Technical Appendix 2.3: Aviation

1.1 Introduction

1.1.1 This Technical Appendix considers the likely significant effects on aviation associated with the construction, operation and decommissioning of the Proposed Development. This section also considers the aviation obstacle lighting requirements for the Proposed Development.

1.1.2 This Technical Appendix has been prepared by Mackenzie Renewables Limited. Anne Mackenzie, Mackenzie Renewables principal, is an industry expert on the aviation and renewable energy interface, with over twenty years' experience from both aviation and renewable energy perspectives and has previously been employed by Infratil Airports Europe to safeguard its airports in respect of windfarms and by ScottishPower Renewables as its senior aviation manager during which time Anne *inter alia* chaired RenewableUK's aviation working group and was an industry representative on the UK Government's Aviation Management Board.

1.2 Methodology

1.2.1 The assessment of potential effects on aviation and radar within this Technical Appendix considers technical acceptability, based on air navigation safety, rather than following a strict Environmental Impact Assessment (**EIA**) process of assessing the significance of effects. Such effects often require the implementation of technical mitigation solutions to ensure continued safe operation in the presence of a wind farm. The assessment of effects on these receptors is therefore one of technical analysis and consultation and seeks to identify whether the effect is likely to be 'acceptable' or 'not acceptable' for air navigation service provision.

1.2.2 Mackenzie Renewables' analysis is informed by radar line of sight (**RLOS**) modelling by Cyrrus Limited, using HTZ Communications V2023.5.1 to undertake the assessment, utilizing United Kingdom 25 m EPSG3035 Projection terrain data, and Primary Surveillance Radar (**PSR**) positions taken from both Ofcom's Protected Radar List (2023) as well as data held on file by Cyrrus.

1.3 Legislation, Policy and Guidance

1.3.1 The Air Navigation Order 2016 (**ANO**)[1] governs, inter alia, arrangements for air traffic services and requirements for aerodromes and lighting, including a requirement to light objects, such as wind turbine generators, which may prove an obstacle to aircraft.

1.3.2 The Civil Aviation Authority (**CAA**) Publication (**CAP**) 764, Policy and Guidelines on Wind Turbines (7th edition, December 2025)[2] is the primary guidance in relation to the assessment of wind turbines on aviation in the UK. It signposts the other relevant regulatory CAPs and guidance for consideration, including:

- CAP670: Air Traffic Services Safety Requirements (3rd issue, 2019)[3]
- CAP493: Manual of Air Traffic Services Part 1 (12th edition, 2025)[4]
- CAP774: UK Flight Information Services (4th edition, 2021)[5]
- CAP168: Licensing of Aerodromes (13th edition, 2025)[6]
- CAP738: Safeguarding of Aerodromes (3rd edition, 2020)[7]
- CAP785B: Implementation and Safeguarding of Instrument Flight Procedures in the UK (2nd edition, v.2, 2022)[8]
- CAP777: Air Traffic Control Surveillance Minimum Altitude Chart (4th edition, 2017)[9]
- CAP793: Safe Operating Practices at Unlicensed Aerodromes (1st edition, 2010)[10]
- CAP1096: Guidance to Crane Users on Aviation Lighting and Notification (edition 2.2, 2021)[11]
- MOD Obstruction Lighting Guidance (RAF, 2020)[12]

1.3.3 Planning Circular 2/2003, Safeguarding of Aerodromes, Technical Sites and Military Explosives Storage Areas[13], contains annexes which describe the formal process by which planning authorities should take into account aviation safeguarding, including in relation to wind energy developments.

1.3.4 National Planning Framework 4 (**NPF4**)[14] Policy 11(a) states that development proposals for all forms of renewable, low-carbon and zero emissions technologies (including windfarms) will be supported. In addition, project design and mitigation is to demonstrate how impacts on various receptors are addressed, including aviation and defence interests (see Policy 11(e)).

1.3.5 The Scottish Onshore Wind Policy Statement 2022 (published December 2022) (**2022 OWPS**)[15] notes the potential impacts of wind developments, especially on radar. The 2022 OWPS in discussing mitigation suggests a longer-term strategic direction towards co-existence between aviation and wind interests, with the deployment of such cost neutral mitigation by 2030. The 2022 OWPS makes it clear that any mitigation should not generate profits for aviation stakeholders, thus ensuring security of green energy supply and low-cost green energy generation.

1.3.6 CAP764 (7th edition) echoes the Department for Energy Security and Net Zero (**DESNZ**)'s December 2025 Overarching National Policy Statement for Energy (**EN-1**)[16] and DESNZ's July 2025 Onshore Wind Taskforce Strategy[17], each recognising that aviation and renewables (wind) are important to UK national interest and that both industries have legitimate interests that must be balanced carefully, with a view to establishing "win-win" outcomes. All three documents recognise that as existing Communications, Navigation and Surveillance (**CNS**) infrastructure reaches the end of its operational life, replacement options that are more tolerant of wind turbines should be installed if available. In other words, wind turbines will form part of operational baseline for which replacement CNS equipment should be procured.

[1] Available at: https://www.legislation.gov.uk/uksi/2016/765/contents (accessed March 2026)
[2] Available at: https://www.caa.co.uk/publication/download/14561 (accessed March 2026)
[3] Available at: https://www.caa.co.uk/publication/download/17362 (accessed March 2026)
[4] Available at: https://www.caa.co.uk/publication/download/20755 (accessed March 2026)
[5] Available at: https://www.caa.co.uk/publication/download/19298 (accessed March 2026)
[6] Available at: https://www.caa.co.uk/publication/download/26459 (accessed March 2026)
[7] Available at: https://www.caa.co.uk/our-work/publications/documents/content/cap-738/ (accessed March 2026)
[8] Available at: https://www.caa.co.uk/publication/download/13875 (accessed March 2026)
[9] Available at: https://www.caa.co.uk/publication/download/20568 (accessed March 2026)
[10] Available at: https://www.caa.co.uk/publication/download/13965 (accessed March 2026)
[11] Available at: https: https://www.caa.co.uk/publication/download/14615 (accessed March 2026)
[12] Available at: https://www.contarnex.com/infrared-obstruction-lighting/MOD%20Obstruction%20Lighting%20Guidance%202020.pdf (accessed March 2026)
[13] Scottish Government (2016) The Town and Country Planning (Safeguarded Aerodromes, Technical Sites, Meteorological Technical Sites and Military Explosives Storage Areas) (Scotland) Direction, 2016. Available at: https://www.gov.scot/publications/planning-circular-2-2003-scottish-planning-series-town-country-planning-0755923111/pages/4/ (accessed March 2026)
[14] Available at: https://www.gov.scot/publications/national-planning-framework-4/ (accessed March 2026)
[15] Available at: https://www.gov.scot/publications/onshore-wind-policy-statement-2022/ (accessed March 2026)
[16] Available at: https://assets.publishing.service.gov.uk/media/6915ba42bc34c86ce4e6e726/overarching-national-policy-statement-for-energy-en-1-web-accessible.pdf (accessed March 2026)
[17] Available at: https://assets.publishing.service.gov.uk/media/68678b6bd520affe4e581cc1/onshore-wind-taskforce-strategy.pdf (accessed March 2026)

1.4 Aviation Concerns with Wind Turbines

1.4.1 Aviation stakeholders object to proposed wind farm developments in the planning system where they consider that the turbines would have unacceptable impacts on aviation infrastructure and/or operations which may either impact safety or the efficiency and commercial prospects of the aviation stakeholder. For an objection to be sustained, the aviation stakeholder needs to:

- Establish and evidence a technical impact on its:
  - Aerodrome Obstacle Limitation Surfaces (**OLS**) (which extend to c. 15km from the aerodrome) and/or
  - Aerodrome Instrument Flight Procedures (**IFPs**) (which may extend out to 56km / 30nm from an aerodrome) and/or
  - CNS infrastructure including impact on PSR, secondary surveillance radar (**SSR**) or air-ground-air communications (**AGA**) infrastructure, then
- Establish that this demonstrated technical impact has a detrimental impact on the provision of a safe and efficient air traffic service (**ATS**) it provides, or on the safety of its aerodrome or IFPs; and only then
- Establish what reasonable measures (operational or technical) can be put in place to mitigate the impacts of the wind turbines on its service or operations.

1.4.2 Wind turbines are an issue for aviation PSR as the characteristics of a moving wind turbine blade are similar to that of an aircraft. Legacy PSR have been unable to differentiate between wanted aircraft targets and unwanted clutter targets introduced by the presence of wind turbines.

1.4.3 Wind turbines can have an impact on SSR, but such impacts are markedly less than on PSR performance.

1.4.4 Wind turbines may adversely affect the ability of an Air Navigation Service Provider (**ANSP**) to provide an ATS because of degradation of radio signals emitted by aeronautical radio stations due to multi-path inference caused by reflection from the static elements or signal modulation effects due to rotating turbine blades, that is detrimental impacts on AGA infrastructure.

1.4.5 SSR and AGA impacts tend to be confined to situations where the wind turbines are relatively close to the CNS infrastructure.

1.4.6 The significance of any technical impact (PSR, SSR or AGA) depends on the airspace usage in the vicinity of the Proposed Development.

1.5 Scoping responses

1.5.1 The following table summarises the scoping responses from the various aviation stakeholders in respect of the Proposed Development and outlines the Applicant's response.

Table 2.3.1: Aviation Scoping Responses

Consultee	Summary of Consultation Response	Applicant's Response
NATS (En Route) plc (**NERL**) TOPA SG39557 Issue 1, June 2025	**PSR**: Proposed Development's turbines are in RLOS of Lowther Hill PSR and Cumbernauld PSR, both of which feed into NERL's Multi-Radar Tracking (**MRT**) system – NERL's Prestwick Centre ATC consider this PSR impact to be unacceptable without mitigation	This has been noted. The Applicant is therefore currently in discussion with NERL on a portfolio basis as to the optimal mitigation strategy (either optimisation of the Lowther Hill Indra PSR or blanking and infill using a feed from Glasgow Airport's Terma Scanter 4002) and its concomitant commercial terms. The Applicant is prepared to meet reasonably and demonstrably incurred costs of NERL in implementing the selected mitigation in respect of the Proposed Development. Mitigation implementation costs should not include ongoing operation and maintenance payments nor capital contributions for operational infrastructure.
NATS (En Route) plc (**NERL**) TOPA SG39557 Issue 1, June 2025	**SSR**: Degradation in the performance of the SSR co-located with the PSR at Lowther Hill is anticipated. NERL added, "Work is ongoing to fully understand the technical impact and subsequently determine how operationally significant or not this is likely to be."	Early in the development process the Applicant recognised the potential for SSR impacts due to the Proposed Development's proximity to the Lowther Hill SSR and engaged with NERL. The Applicant commissioned QinetiQ (**QQ**) to undertake SSR modelling – NERL had previously accepted QQ SSR modelling with regards to the Clyde Wind Farm. In March 2025 the Applicant supplied NERL with detailed QQ modelling and has been seeking engagement with NERL since to discuss these findings to determine what, if any, impacts are either technically or operationally unacceptable to NERL and so identifying any necessary mitigation strategy. The QQ modelling is being refreshed in light of design freeze layout (which saw the elimination of the scoping turbines closest to the SSR) and will be shared with NERL in due course for discussion.
NATS (En Route) plc (**NERL**) TOPA SG39557 Issue 1, June 2025	**Navigation Aids**: no impact is anticipated on NERL's navigation aids.	Noted: no further consideration required.
NATS (En Route) plc (**NERL**) TOPA SG39557 Issue 1, June 2025	**AGA**: NERL writes, "It is clear that there will be some degradation in the performance of the Lowther Hill air ground air installation from some of the closer, higher turbines. Work is ongoing to determine the likely volume within which this degradation is likely to occur and subsequently determine how operationally significant or not this is likely to be."	As with the potential SSR impacts, the Applicant recognised early in the development process the potential for AGA impacts due to the Proposed Development's proximity to the Lowther Hill AGA infrastructure and engaged with NERL. The Applicant commissioned QinetiQ (**QQ**) to undertake AGA modelling. In March 2025 the Applicant supplied NERL with detailed QQ modelling and has been seeking engagement with NERL since to discuss these findings to determine what if any impacts are either technically or operationally unacceptable to NERL and so identifying any necessary mitigation strategy. The QQ modelling is being refreshed in light of design freeze layout (which saw the elimination of the scoping turbines closest to the AGA infrastructure) and will be shared with NERL in due course.
Aberdeen Airport, 20 June 2025	Outwith consultation area of Aberdeen Airport – no comment and no need for further consultation	Noted: no further consideration required.
Edinburgh Airport, 2 July 2025	Proposed Development does not conflict with aerodrome safeguarding criteria	Noted: no further consideration required.
Glasgow Airport (**GLA**), 27 June 2025	Outwith GLA's OLS but IFP safeguarding may be impacted, necessitating assessment once turbine details finalised.	Noted. Responsibility for IFP safeguarding rests with the aerodrome. At 33.6nm from GLA's aerodrome reference point, the Proposed Development is likely to be outwith

Table 2.3.1: Aviation Scoping Responses		
Consultee	**Summary of Consultation Response**	**Applicant's Response**
		GLA's IFP safeguarding zone. Unlike GPA, GLA does not yet have any Required Navigation Performance (RNP) IFPs. The M74W Renewable Energy Park is closer to GLA than the Proposed Development and did not attract any IFP objection upon application although was met with the same standard words at scoping.
Glasgow Prestwick Airport (**GPA**), 11 June 2025	**IFP**: GPA indicated a holding objection on grounds of potential impact to its RNP IFP for Runway 30, relevantly the Terminal Arrival Altitude (**TAA**) which at the date of writing was set at 3800ft above mean sea level (**amsl**). GPA stated it would require an IFP assessment unless this TAA was increased to 3900ft amsl. GPA then indicated that works were underway to raise the TAA level to 3900ft amsl (in connection with an IFP scheme for the Sanquhar II Wind Farm) and that if the TAA were raised to 3900ft amsl, GPA's holding objection would fall away provided that all of the Proposed Development's turbines remain below 2900ft amsl.	Noted. Responsibility for IFP safeguarding rests with the aerodrome. The 25 nautical mile (**nm**) TAA from the waypoint SKARV was raised to 3900ft amsl on 12 September 2025 – see Instrument Approach Chart RNP RWY30 as published in the AIP AD 2-EGPK-8-14. Given the TAA is now 3900ft amsl, this eliminates the requirement for an IFP assessment for the Proposed Development. The turbine locations, elevations and micro-siting buffers can be made available to GPA to enable it to complete its IFP safeguarding assessment and remove its holding objection. The Applicant is prepared to undertake that no part of any of the Proposed Development's turbines will exceed 2900ft amsl. All of the turbine heights as presented within the consent application are within this parameter, and the Applicant would be content to accept a suitably worded planning condition restricting the final turbine tip height to below this level (once any further micrositing is completed).
Glasgow Prestwick Airport (**GPA**), 11 June 2025	**PSR**: GPA stated that there was no likelihood that the Proposed Developments turbines would be in RLOS of its PSR	Noted: no further consideration required.
Highlands and Islands Airports Limited (**HIAL**), 20 June 2025	Outwith HIAL's safeguarding criteria – no objection	Noted: no further consideration required
Defence Infrastructure Organisation (**DIO**) for the Ministry of Defence (**MOD**), 16 July 2025	Physical obstructions / low flying impacts given the Proposed Development is located with Low Flying Tactical Training Area T20 where fixed wing aircraft can operate as low as 100ft/30.5m above ground level. Appropriate notification, lighting and charting would be required.	This has been noted by the Applicant. The Applicant will chart and light the Proposed Development in accordance with civil and military aviation requirements, discussed further below.

1.6 Stakeholder engagement outwith scoping

1.6.1 The following table summarises the engagement between the Applicant, NERL and the CAA in respect of the Proposed Development outwith the formal EIA Scoping process.

Table 2.3.2: Engagement Outwith Scoping		
Consultee	**Form of engagement**	**Engagement content**
NATS (En Route) plc (**NERL**)	Letter from Mackenzie Renewables for the Applicant to NERL Safeguarding dated 2 July 2024	Given the proximity of the Proposed Development to NERL's Lowther Hill CNS infrastructure, the Applicant sought early engagement with NERL with regards to potential PSR, SSR and AGA impacts, in an effort to identify hard constraints during the design process.
NATS (En Route) plc (**NERL**)	Email from NERL Safeguarding to Mackenzie Renewables dated 3 July 2024	NERL Safeguarding responded to Mackenzie Renewables' 2 July 2024 letter explaining that there appears to be no "hard limit" on turbines nearby the PSR, SSR modelling would be required but anticipated that any impacts will be acceptable given previous acceptability of similar impacts from the North Lowther Energy Initiative, and AGA C/I modelling would be required.
NATS (En Route) plc (**NERL**)	Letter from Mackenzie Renewables to NERL Safeguarding dated 5 March 2025, appending detailed QQ SSR and AGA C/I modelling	QQ SSR and AGA modelling sent to NERL for consideration. Engagement with NERL on SSR and AGA impacts again requested, in order to inform further design options. The Applicant acknowledged that some of the turbines may prove challenging for NERL but sought clarification as to where this judgement would be made by NERL. The Applicant also requested guidance as to which PSR mitigation option NERL would seek with respect to the acknowledged RLOS of the turbines to Lowther Hill and Cumbernauld PSRs.
NATS (En Route) plc (**NERL**)	Email from NERL Safeguarding to Mackenzie Renewables dated 28 March 2025	NERL indicated that it was in discussion with the CAA on AGA impact assessment methodology given the increased turbine size since the CAP670 guidance was drafted and acknowledged that NERL would need to undertake detailed C/I assessment as part of its safeguarding duties. NERL indicated that any concerns it would have with regards to SSR impacts were unlikely to be "false plots" but rather risk of "shadowing / bearing errors" arising from turbine located on higher locations. The Applicant notes that the QQ study focuses on SSR bearing errors. Finally, NERL indicated that it would need to engage with the Lowther Hill PSR supplier, Indra, as to the inner limit of any Indra optimisation mitigation capability.
NATS (En Route) plc (**NERL**)	Email from Mackenzie Renewables to NERL Safeguarding dated 31 March 2025	Reforwarded QQ SSR and AGA modelling and summarised key findings of QQ modelling – again sought engagement on QQ modelling to determine if any turbine locations were "show-stoppers".
NATS (En Route) plc (**NERL**)	Email from NERL Safeguarding to Mackenzie Renewables dated 14 May 2025	NERL Safeguarding explained that NERL was still considering the details provided and was of the opinion that a meeting with QQ would not be particularly helpful, acknowledging that QQ "have undertaken a quality piece of work, we understand their methodology, assumptions and how they have reached the conclusions they have come to." NERL Safeguarding then suggested that the CAP670 C/I methodology was an "instruction" from the CAA and that the QQ modelling was both more and less conservative that then CAP670 modelling and added: "It is these differences and their operational implications that are driving our tardiness in formally responding."
NATS (En Route) plc (**NERL**)	Email from NERL Safeguarding to Mackenzie Renewables dated 16 July 2025	NERL Safeguarding explained that the QQ work had "led to many interesting debates internally", but that NERL considered itself "duty bound" by the CAA to follow the CAP670 methodology precisely. Again, NERL Safeguarding acknowledged the general equivalence between the QQ and NERL's inhouse CAP670 modelling, noting that QQ's

Table 2.3.2: Engagement Outwith Scoping		
Consultee	**Form of engagement**	**Engagement content**
		modelling only differed in the extent of the vertical dimension. NERL Safeguarding added that only once it has settled the modelling issue could it move to define a volume of impact that NERL Safeguarding would be comfortable with and then compare this against NERL's operational coverage requirement. As is noted in the discussion on AGA modelling below, an operational assessment by an ANSP is required before a conclusion can be reached that the AGA impacts have a detrimental impact on that ANSP's ATS and thus require mitigation. The apparent absence of empirical evidence of AGA impacts from operational turbines should inform views of modelling robustness.
Civil Aviation Authority (**CAA**)	Letter from Mackenzie Renewables to CAA dated 24 July 2025	Mackenzie Renewables sought guidance from the CAA as to whether the CAP670 C/I methodology was the only means of undertaking AGA safeguarding modelling and noted that absence of empirical evidence for AGA impacts from operational turbines.
Civil Aviation Authority (**CAA**)	Email from CAA to Mackenzie Renewables dated 26 August 2025	CAA responded to Mackenzie Renewables' enquiry but explaining that "the methodology material in CAP670 GEN02 is guidance and that within the discussion/negotiations between ANSPs and developers there is no hard and fast rule on the methodology that can be used. It would be wrong to describe the guidance material provided as specific 'instructions' or that parties are 'duty bound' to follow the process defined. A definition of this guidance material could be summarised as 'non-binding explanatory and interpretation material on how to achieve the requirements in the applicable regulations'."
NATS (En Route) plc (**NERL**)	Letter from Mackenzie Renewables to NERL Safeguarding dated 30 September 2025	Mackenzie Renewables shared the CAA's response on CAP670 with NERL Safeguarding and once again asked for feedback to inform the Proposed Development's final design. NERL Safeguarding was also once again asked for guidance on acceptable PSR mitigation – namely whether it would be Indra optimisation or MRT blanking and GLA Terma infill.
NATS (En Route) plc (**NERL**)	Email from Mackenzie Renewables to NERL Safeguarding dated 22 October 2025	Email chasing for response to 30 September 2025 letter, again observing that as the Proposed Development's final design is being worked on in light of scoping responses, now would be the optimal time for any NERL concerns to be shared.
NATS (En Route) plc (**NERL**)	NERL Safeguarding email to Mackenzie Renewables dated 20 April 2026	NERL Safeguarding explained that only the formal submission of the Watchman application enabled the safeguarding team to "pin down the right people" to "have a think about the radio impact." Consequently, NERL Safeguarding would be changing its position of scoping non-objection on AGA grounds to one of objection for Watchman. NERL Safeguarding intimated that while NERL agreed the horizontal extent of QQ's modelling, its modelling remained more conservative in the vertical extent, although NERL Safeguarding did acknowledge that this may be over conservative. Given the many operational turbines nearby the Lowther Hill AGA, Mackenzie Renewables considers that there should be ample empirical evidence to support modelling tools. It would be expected that
		such evidence would be shared with the CAA and the Applicant, as envisaged in CAP764.
Civil Aviation Authority (**CAA**)	Letter from Mackenzie Renewables to CAA dated 27 April 2026	Mackenzie Renewables applied for approval on behalf of the Applicant of the reduced lighting scheme set out below.
Civil Aviation Authority (**CAA**)	Letter from CAA to Mackenzie Renewables dated 5 May 2026	CAA issued approval of the reduced lighting scheme sought.

1.7 Baseline conditions

1.7.1 Relevantly for the purposes of this aviation analysis, the Proposed Development consists of up to 21 wind turbines with a maximum tip height of 220m above ground level (**agl**).

Aerodromes

1.7.2 The closest turbine of the Proposed Development is located approximately:

- 27.5nm / 51km east-southeast of GPA
- 34nm / 63km southeast of GLA
- 32nm / 58km south-southwest of Edinburgh Airport
- 2.3nm / 4.7km southeast of the unlicensed 380m long grass airstrip at Stonehill Farm

Airspace

1.7.3 The Proposed Development is in uncontrolled (Class G) airspace extending from ground level to 5,500ft amsl.

1.7.4 Above 5,500ft is Class D controlled airspace, part of the Scottish Terminal Manoeuvring Area (**TMA**) which extends up to Flight Level (**FL**) 195 – approximately 19,500ft amsl. Above FL195 is a different class of controlled airspace.

1.7.5 The Future Airspace Strategy Implementation North (FASI-N) – Scottish Terminal Manoeuvring Area (ScTMA) Airspace Change Procedure being undertaken by NERL (ACP-2019-74) does not introduce changes to the airspace above the Proposed Development.

1.7.6 The key distinguishing feature between controlled airspace and uncontrolled airspace is that pilots require air traffic control (**ATC**) clearance to enter controlled airspace and whilst in it must comply with ATC instructions. Controlled airspace provides a "known traffic" environment meaning that ATC is aware of all traffic operating within the designated airspace. In uncontrolled airspace, the ultimate responsibility for terrain and collision avoidance rests with the aircraft pilot.

NERL CNS infrastructure and air traffic service

1.7.7 NERL provides surveillance/radar-based ATS in the controlled airspace above the Proposed Development.

1.7.8 The surveillance air picture used by NERL's controllers is created using Multi-Radar Tracking (**MRT**). NERL's MRT system creates a synthetic air picture, calculating the best estimate of the position of an aircraft by combining data from multiple radar sources, including secondary radars that provide aircraft altitude information. The algorithms in the MRT are typically configured to weight the calculation of the position towards the radar sensors assessed to provide the highest quality position data.

1.7.9 NERL's Scottish TMA MRT air picture uses surveillance feeds from:

- Lowther Hill PSR/SSR – closest turbine c.2.2nm / 4.1 km north of radar

- Great Dun Fell PSR/SSR – closest turbine c.61.2nm / 113.3 km north-west of radar
- Tiree PSR/SSR – closest turbine c.121.9nm / 225.8 km south-east of radar
- Kincardine PSR (legacy terrain shielded wind farm mitigation PSR) – closest turbine c.37nm / 69km south of radar
- Cumbernauld PSR (legacy terrain shielded wind farm mitigation PSR) – closest turbine c.31nm / 57 km south-south-east of radar
- GLA Terma Scanter 4002 wind farm tolerant PSR (**TS4002**) – on aerodrome
- Edinburgh Airport TS4002 – on aerodrome
- GPA TS4002 – on aerodrome
- Brownsfield SSR near Glasgow Airport

1.7.10 NERL's MRT system uses the 360-degree feed from all contributing surveillance feeds to create the air picture for NERL's controllers, so the radar data from each of the PSR currently contributes to the MRT air picture and will continue to do so for so long as each feeds into MRT.

1.7.11 The data from each surveillance feed is only integrated into NERL's MRT once. This means that once a radar feed is integrated into MRT, there is no need for any infill as that radar feed already exists and is being used in MRT.

1.7.12 Within the Scottish TMA, it is mandatory for all aircraft flying at or above 6,000ft amsl to carry transponders.

1.7.13 The NERL Lowther Hill AGA radio communications transmitter/receivers are located 3.3nm / 5km to the south of the Proposed Development's closest turbine.

Low flying

1.7.14 The Proposed Development is within the daytime military Low Flying Area (**LFA**) 20(T), where fixed wing aircraft may be permitted to fly as low as 100ft agl. For military low flying at night, the Proposed Development is located in Allocated Region 2B, which covers southwest Scotland.

Scoped out issues

1.7.15 The Proposed Development is not within the safeguarding zones for any NERL navigation aids, Meteorological Office radars or military air defence radars. No further consideration is required of these issues.

1.7.16 There is no RLOS between the PSR at GPA, GLA and Edinburgh Airports. As set out in **Table 2.3.1**, no impact on the IFPs of these airports are predicted. These issues have been scoped out from further consideration.

1.7.17 Impacts on Stonehill Farm airstrip have been scoped out as it lies beyond the 3 km consultation distance recommended in CAP764.

1.8 Assessment of potential effects and discussion of mitigation options

NERL PSR

1.8.1 The Applicant accepts that the Proposed Development's turbines will be in RLOS of the Lowther Hill and Cumbernauld PSRs which feed into NERL's MRT air picture and may have a detrimental impact on NERL's ATS. This will require mitigation in the form of removing the turbine returns from the radar feeds into MRT. The critical point is that NERL's controllers' air picture is not degraded but as noted above, it is a synthetic picture crafted from multiple surveillance inputs.

1.8.2 As CAP764 makes clear (see paragraphs 1.20 and 2.43 of CAP764), there must be not only a technical effect to the CNS infrastructure (namely radar impacts generated by turbines), but that technical effect must have a negative impact on the provision of the ATS, and mitigation should be reasonable measures to address that negative impact on ATS provision, namely ensuring the continued provision of a robust air picture for NERL's controllers.

1.8.3 The Applicant is prepared to meet NERL's reasonably and demonstrably incurred costs of implementing the necessary mitigation required to address the detrimental impact on the Proposed Development's RLOS on NERL's ATS. Mitigation implementation costs should not, however, include ongoing operation and maintenance payments nor capital contributions for operational infrastructure.

NERL mitigation options

1.8.4 Removal of the turbine returns from NERL's air picture may be achieved by optimising the Lowther Hill 3D Indra PSR or by applying NERL's legacy "blanking and infill" approach as set out in the Scottish Government's South West Scotland Regional Aviation Solution Group – Final Radar Feasibility Study (February 2010).[18] NERL has confirmed that both these mitigation options are available to the nearby M74W Renewable Energy Park, c. 6km / 3.5nm to the north of the Proposed Development.

1.8.5 NERL's Lowther Hill PSR is a sophisticated 3D Indra PSR with extensive wind farm tolerance capabilities. It became operational in 2022. Like the TS4002 at GLA, GPA and Edinburgh Airport, the wind farm capabilities of the Lowther Hill Indra PSR simply need to be activated over each new wind farm. This is understood to entail some preliminary modelling, creation of the plot suppression zone, configuration and deployment of related system modifications, and testing, updating of safety case documentation.

1.8.6 Optimisation of the Indra PSR will entail some limited loss of low-level cover. However, NERL's ATS is focused on controlled airspace and a buffer beneath of about 2,000ft so that NERL controllers can monitor for any potential controlled airspace incursions (pop-ups).

1.8.7 The Applicant enquired of NERL as early as March 2025 as to whether Lowther Hill Indra PSR optimisation would be a suitable mitigation for the Proposed Development, delivering solid, turbine free cover at c. 3,500ft. NERL has not to date responded to this inquiry.

1.8.8 This same focus on NERL's controlled airspace and a buffer beneath of about 2,000ft is also present in NERL's legacy "blanking and infill" mitigation. NERL is content to blank wind farm footprints in one or more PSR feeds provided it has sufficient redundancy of radar cover from the other feeds inputting into MRT.

1.8.9 Mackenzie Renewables understands that in the airspace above the Proposed Development, the GLA TS4002 has good cover at 3,500ft amsl as does the GPA TS4002 (being 2,000ft below NERL's controlled airspace). The Kincardine PSR has good cover in the airspace above the Proposed Development at 4,500ft amsl. Therefore, there should be sufficient, already MRT integrated, redundant PSR cover above the Proposed Development after blanking the Proposed Development's turbine returns in the Lowther Hill and Cumbernauld PSR.

NERL mitigation costs

1.8.10 In mitigation discussions with NERL on a portfolio basis (with Renewco's other proposals in the region of the Proposed Development), NERL identified that either Indra optimisation or "blanking and infill" using a (terrain shielded) GLA TS4002 feed could be potential PSR mitigation options.

[18] This can be found at Clauchrie WIN-370-3 APP003.013 - South West Scotland Regional Aviation Solution Group Final Radar Feasibility Study https://www.dpea.scotland.gov.uk/Document.aspx?id=752487 (accessed March 2026)

1.8.11 NERL requires that mitigation for its systems and ATS be undertaken by NERL's sister company, NATS (Services) Limited (**NSL**). All mitigation fees are paid to NSL. NERL/NSL have shared their standard mitigation charges for each of Indra optimisation and "blanking and infill" with the Applicant's parent company. These are set out in **Plate 2.3.1** and **Plate 2.3.2** below. NERL/NSL assert that these are "standard charges", unchanged since 2014. This accords with Mackenzie Renewables' experience of the NERL/NSL mitigation offering.

Plate 2.3.1 - NSL charges for "blanking & GLA Terma infill"

NATS MSC Mitigation Services (Blanking)		
Initial Fee	£20,000	Single Payment – Upon Commencement
Implementation fee*	£55,000	Single Payment – Upon Implementation Notice
Service charge *	£10,000 p/a	Annual – Upon Schedule 6 Discharge Notice
Testing Protocol* (IF REQUIRED)	£82,500	Single Payment – Upon Implementation Notice
Upgrade liability *	£10,000 every 5 years	Periodic
Decommissioning cap *	£55,000	Single payment
NATS ORRD Onward Routed Radar Data (Infil GLA Terma)		
Infill Feed cost p/a *	£120,700 p/a**	Annual - pro rata amount payable upon service of the Implementation Notice
**Index Linked* ***Discounted feed cost p/a if Developer is already using feed for another development* *Note- PCG is required once the implementation notice is served* *Note - contract negotiations will require legal involvement and associated charges apply*		

Plate 2.3.2 - NSL charges for Lowther Hill Indra optimisation

INDRA (MMS) Breakdown			
Payment Profile	**Index Linked**	**Cost**	**Frequency**
Initial Services	N/A	£20,000	Single payment
Implementation Services (A)	Index Linked	£55,000	Single payment
Implementation Services (B) CAPEX	Index Linked	£32,000 x Installed MW capacity (Capped at 50MW)	Single payment
O&M Costs	Index Linked	£97,759 x Operational Years	Annual
Upgrade and Decommissioning	Index Linked	£17,500 x Operational Years	Annual
Annual Fixed Liabilities (see Table A below for options)	Index Linked	£20,000	Annual
Legal Fees	Index Linked	TBC	Single Payment

(Table A)

Liability	Context	Type of Liability	Risk Bearer	Liability Cost
The Developer shall pay the costs and liabilities incurred by NATS inter alia the maintenance, upgrading and decommissioning of the plot suppression zone blanking of the radar coverage and/or the decommissioning of the New Radar which shall incorporate and is include all liabilities in relation to i) the Decommissioning Works, ii) mid-life upgrade liabilities and iii) the Upgrade Liabilities up to a sum of up to five million pounds (£5,000,000)	Developer wants this derisked (fixed liability) NATS will bear the risk but will require a £20k per annum fixed fee.	Fixed Liabilities	NATS	£20k per Annum
	Developer assumes responsibility wants to take the liabilities risk (unfixed liability)	Unfixed Liabilities	Developer	Up to £5m

Reasonable and unreasonable mitigation costs

1.8.12 The August 2023 Clauchrie and Sanquhar II decisions[19] made clear that the extent of mitigation required to be supported by a developer is also strictly constrained by the planning system. The reporters in both cases concluded, based on Circular 4/1998 pertaining to planning conditions, that:

- It is not appropriate to include an ongoing maintenance component in any radar mitigation scheme or condition[20]
- Leaving the scope of mitigation to be determined at a later date through a mitigation services agreement would leave a great deal of uncertainty as to what was to be required and the potential costs for the developer – and this lack of precision would run counter to the requirements set out in Circular 4/1998[21]
- A per MW basis for the calculation of any contribution would not be appropriate as a per MW fee is an illogical approach to mitigate specific impacts: "*the size and position of turbines … would influence the need for mitigation and the associated costs, rather than their electrical output*"[22]
- A condition setting out the headline mitigation actions is to be preferred and would best meet the requirements of Circular 4/1998[23]

1.8.13 The Scottish Ministers concluded in both Clauchrie and Sanquhar II that the developer should only have to pay the "*costs associated with specific mitigation measures identified to address the evident impacts of the development, acknowledging that the sums of these costs should be demonstrably incurred by … [the relevant aviation stakeholder], and that there is no basis for ongoing compensatory payments to be made*" (emphasis added).[24]

1.8.14 Applying this reasoning to the NERL/NSL "standard" mitigation offering:

- The reasonable mitigation charges are:
  - Initial Fee (blanking and infill) / Initial Services charge (Indra optimisation) of £20,000
  - Implementation Fee (blanking and infill)[25] / Implementation Services (A) (Indra optimisation) of £55,000 (index linked)
  - NERL reasonably and demonstrably incurred legal fees
- The unreasonable charges for the "blanking and GLA TS4002 infill" mitigation are:
  - Annual service charge: this is something NERL should be routinely undertaking, irrespective of "patches"
  - Periodic upgrade liabilities: this is something NERL should be routinely doing as required, irrespective of "patches"
  - Decommissioning fees: given that the operational life of the Proposed Development is double that of NERL's PSRs, it seems unlikely that there will be any reversion to the baseline conditions prior to the establishment of wind generation, over 25 years ago
  - Annual GLA TS4002 Onward Routed Radar Data (**ORRD**) charge: The GLA TS4002 ORRD feed is already in operation in NERL's MRT in the airspace over the Proposed Development. Radar data only "goes down the line once" – there is no "infill feed" required as the GLA TS4002 data is already being used in MRT in the airspace above the Proposed Development
- The unreasonable charges for the "Indra optimisation" mitigation are:
  - Implementation Services (B) – per MW "capex" contribution (capped at 50MW) for an already operational NERL PSR: the Applicant understands that the costs of, inter alia, CNS infrastructure required by NERL to provide its en-route ATS are recovered from its aeronautical customers (largely airlines) under NERL's regulated charges – there should be no requirement for developers / energy consumers to fund essential aeronautical CNS infrastructure capex. Further NATS Holdings, NERL's parent company, made it clear that the replacement of NERL's long-range PSR fleet is a NATS Group investment[26]. Finally, as the Clauchrie and Sanquhar II reporters observed, a per MW mitigation contribution is not a logical approach to mitigate the specific impacts of the Proposed Development on NERL's PSR and ATS

[19] Clauchrie windfarm – see https://www.energyconsents.scot/ApplicationDetails.aspx?cr=ECU00002001; Sanquhar II windfarm – see https://www.energyconsents.scot/ApplicationDetails.aspx?cr=ECU00001801

[20] Clauchrie inquiry report dated 8 March 2023 paragraph 6.33 - https://www.dpea.scotland.gov.uk/Document.aspx?id=1107052 and Sanquhar II inquiry report dated 1 March 2022 paragraph 4.91 - https://www.dpea.scotland.gov.uk/Document.aspx?id=1004778

[21] Clauchrie inquiry report dated 8 March 2023 paragraph 6.33

[22] Sanquhar II inquiry report dated 1 March 2022 paragraph 4.86

[23] Clauchrie inquiry report dated 8 March 2023 paragraph 6.33 and Sanquhar II inquiry report dated 1 March 2022 paragraph 4.93 – both reporters adopted the condition to this effect proposed by SPR at Clauchrie and adopted by Sanquhar II

[24] Clauchrie decision letter 31 August 2023, https://www.dpea.scotland.gov.uk/Document.aspx?id=1107053, page 16; Sanquhar II decision letter 31 August 2023, https://www.dpea.scotland.gov.uk/Document.aspx?id=1046845, pages 14-15

[25] Testing protocol would be a reasonable charge if TS4002 optimisation were required – this is not required for the Proposed Development as it is not in RLOS of GLA TS4002

[26] NATS Holdings Limited, NERL and NSL's parent company, announced in its 2025 annual report an investment of £120m to replace ten (and decommission two) of its long range PSR with Indra 3D PSR as already installed at Lowther Hill – with then new PSR to have an operational life until 2045

- Annual O&M costs: this is something NERL should be routinely doing given that the Lowther Hill PSR is central to NERL's CNS infrastructure supporting its en-route ATS provision, the costs of which are recovered from NERL's aeronautical customers (largely airlines)
- Annual upgrade and decommissioning fee – this has also been called a "through life service charge" – one assumes it is the Indra optimisation equivalent of the blanking and infill annual service charge: this is something NERL should be routinely doing to maintain this core CNS infrastructure
- Annual fixed liabilities charge – it is unclear how this differs from the annual upgrade and decommissioning fees and given that the Proposed Development will have an operational life longer than the Lowther Hill Indra, it is extremely unlikely that the mitigation optimisation will require to be reversed

1.8.15 If the Applicant is required to pay NERL/NSL's "standard" charges, including the (a) capex recovery or an additional GLA TS4002 ORRD feed AND (b) whole of life O&M and related charges, assuming a 40-year operational life, this will mean GB electricity consumers will be paying to NERL/NSL between c. £5.5m and £7.1m more than is required to implement the selected mitigation for the Proposed Development. See **Table 2.3.3**.

Table 2.3.3: NERL/NSL mitigation charges applicable to the Proposed Development

NERL/NSL "standard" mitigation charges applied to Proposed Development (40-year operational life)	Aggregate Amount – today's £ (no indexation)
Reasonable mitigation charges – blanking & infill OR Indra optimisation: initial fee & implementation costs (* plus NATS legal fees)	£75,000*
	PLUS, EITHER
Unreasonable mitigation charges – blanking & infill: annual service charge, periodic upgrade liabilities, decommissioning costs, annual ORRD fee for existing GLA TS4002 feed	£5,480,000
	OR
Unreasonable mitigation charges – Indra optimisation: capex contribution, annual O&M Costs, annual upgrade / decommissioning fee (service charge), annual fixed liabilities fee	£7,150,000

1.8.16 In effect, GB electricity consumers via the Applicant would be funding the provision of essential aviation infrastructure, the costs of which are also being recovered from NERL's aeronautical customers.

1.8.17 Further, by seeking mitigation for the entire operational life of the wind farm, not just the remaining operational life of the legacy CNS infrastructure which is impacted, NERL/NSL's "standard" mitigation contractual and charging structure contradicts CAP764 7th edition and EN-1 which makes it clear that when replacing legacy CNS equipment in future (approx. every 15-20 years), aviation stakeholders are expected to look to deploy future-proofed, windfarm tolerant systems. In other words, the operational wind turbines in 2045 (when the NERL Indra PSR fleet will be due for replacement) will be part of the baseline-built environment for which any replacement CNS systems are procured.

An appropriate aviation suspensive condition is available

1.8.18 The Applicant does not contest the requirement for mitigation for NERL but considers it should only be required to pay NERL's reasonably and demonstrably incurred costs of NERL implementing its selected mitigation and should not be required to pay the unreasonable so-called mitigation costs outlined above.

1.8.19 To this end, the Applicant proposes an aviation suspensive condition which can be imposed to ensure that NERL will be reimbursed its reasonably and demonstrably incurred mitigation costs referable to the Proposed Development, but no further costs.

1.8.20 The Applicant proposes a condition based on the model condition set out in the Onshore Wind Aviation Radar Delivery Group 2030 (**Onward2030**) recent publication, the Onshore Wind Sector Deal Recommendations of Work Package 5 Group – Transparency (**WP5**) (20 March 2025)[27].

1.8.21 WP5 gave the form and wording of aviation suspensive conditions significant thought and proposed a model condition as follows:

"The Developer shall not hang any wind turbine blades until the [insert decision maker], in consultation with the Civil Aviation Authority, are satisfied that the Developer has put in place a binding undertaking to pay [the aviation interest] such sums as are demonstrably and reasonably incurred by [the aviation interest] in [insert agreed scope of mitigation]

Reason: in the interests of aviation safety, and to ensure the impact of the development on the systems of [the aviation interest] is adequately mitigated."

1.8.22 The background to the model condition is set out in the Onward2030 publication:

"2.4 The developer of the proposed wind turbines should provide a binding undertaking to meet the demonstrable costs of delivering the mitigation required to reduce any impact on the aviation interest to an objectively safe level. The undertaking would provide that once such mitigation has been installed or implemented (e.g. through an enhancement to a technical installation or a modification to the aviation interest's procedures), the aviation interest should provide details of the actual costs incurred to the developer. The developer would then reimburse the aviation interest for those costs.

"2.5 It is not appropriate for the developer to be required to meet ongoing costs of the aviation interest during the life of the windfarm. Once the relevant mitigation measure has been implemented, it becomes part of the aviation interest's operational system for which it will be responsible under the relevant legislation that governs its ability to provide relevant aviation services."

Proposed suspensive condition to address NERL's PSR objection

1.8.23 The suspensive condition proposed by the Applicant to address NERL's PSR objection is as follows:

There shall be no Commencement of Development until the Scottish Ministers, in consultation with the Civil Aviation Authority, are satisfied that the Developer has put in place a binding undertaking to pay NATS (En Route) plc such sums as are demonstrably and reasonably incurred by NATS (En Route) plc in [if blanking & infill is the selected mitigation] implementing a plot suppression zone which comprises blanking of the radar coverage from the Lowther Hill PSR and the Cumbernauld PSR, along with associated adaptation changes (including those that may be required for Multi-Radar Tracking) OR [if Indra optimisation is the selected mitigation] configuring and deploying system modifications to the Lowther Hill PSR.

Reason: in the interests of aviation safety, and to ensure the impact of the development on the systems of NATS (En Route) plc is adequately mitigated.

1.8.24 The scope of the mitigation services set out in the proposed condition reflects the scope of mitigation implementation services in NERL/NSL's "standard form" mitigation contracts.

Why this form of suspensive condition is preferable

1.8.25 This form of condition is proposed in preference to that of the Energy Consents Unit (**ECU**) standard s.36 onshore wind conditions of February 2025 as the ECU standard condition may result in uncertainty

[27] Available at: https://www.scottishrenewables.com/publications/1919-recommendations-of-the-onward-2030-work-package-5-group-transparency (accessed March 2025)

as the scope of mitigation is left to be determined at a later date and this lack of precision would seem to run counter to the requirements set out in Circular 4/1998.

1.8.26 This Applicant's proposed condition has the added advantage of incentivising the Applicant to ensure that the binding undertaking is delivered promptly so the Proposed Development can proceed to timely construction and operation, thus contributing to Scotland and the UK's 2030 and beyond onshore wind deployment targets.

NERL SSR

1.8.27 Early in the development process (July 2024), the Applicant recognised the potential for SSR impacts due to the Proposed Development's proximity to the Lowther Hill SSR and engaged with NERL. NERL applies a 15nm (28.5km) safeguarding zone to its SSR, although Eurocontrol applies a 16km consultation zone[28] and the CAA stated in 6th edition of CAP764[29] that SSR impacts rarely seen beyond 10km from the SSR radar head. In terms of potential SSR impacts from wind turbines, there is a potential for:

- uplink and downlink interference (also knowns as "false plots"), but this has a localised impact and was confirmed by NERL in March 2025 not to be of concern;
- SSR bearing errors which can occur behind the turbine and, where the turbine is above the horizon, extend to the radar's maximum range; where the turbines are below the horizon, SSR bearing error impacts will be truncated by the terrain behind the turbines. NERL confirmed in March 2025 that bearing errors were the SSR safeguarding issue relevant to the Proposed Development.

1.8.28 SSR bearing errors occur at lower altitudes, behind the turbines from the radar's viewpoint. This is where NERL's operational assessment is required: if the predicted SSR bearing errors occur in airspace in which NERL does not provide an ATS (or actively monitor to buffer its ATS in controlled airspace), then there is no detrimental impact on NERL's ATS and so there are no grounds for an SSR objection or for requiring any SSR mitigation.

1.8.29 The Applicant commissioned QinetiQ (**QQ**) to undertake SSR modelling – NERL had previously accepted QQ SSR modelling with regards to the Clyde Wind Farm.

1.8.30 In March 2025 the Applicant supplied NERL with detailed QQ modelling which included an SSR bearing error assessment for the Proposed Development, together with operational developments (including Clyde and Clyde Extension wind farms) and other developments in planning. The Applicant has been seeking engagement with NERL since March 2025 since to discuss these findings and determine what, if any, impacts are either technically or operationally unacceptable to NERL and so identifying any necessary mitigation strategy.

1.8.31 The QQ modelling is being refreshed to reflect the design freeze layout which saw the removal of the turbine locations closest to Lowther Hill and updating the Proposed Development's turbine parameters (particularly tower diameter). The revised QQ report will be shared with NERL in due course for discussion.

1.8.32 The initial QQ study shared with NERL in March 2025 established that while there may be some SSR bearing errors arising from the Proposed Development's turbines, as there are SSR bearing errors arising from operational windfarms, the vertical extent of the impact is in the case of tower impacts, below the turbine tip height, and in the case of intermittent blade impacts, is below 4,000ft amsl at the edge of the TMA.

1.8.33 Given that controlled airspace extends upwards from 5,500ft amsl and transponder carriage is mandatory at 6,000ft amsl in the TMA, the initial QQ modelling indicates that NERL should have sufficient buffer beneath these altitudes where there is no SSR bearing error to detrimentally impact the ATS it provides, in much the same way as SSR bearing errors arising from operational turbines (including Clyde and Clyde Extension) do not detrimentally impact the ATS NERL provides.

1.8.34 The Applicant looks forward to sharing with and engaging with NERL on the revised QQ modelling taking into account the design freeze layout and turbine parameters of the Proposed Development. The Applicant anticipates that any SSR bearing impacts arising from the Proposed Development will not be operationally significant for NERL's ATS and will not therefore give rise to an objection.

NERL AGA

1.8.35 Early in the development process (July 2024), the Applicant recognised the potential for AGA impacts due to the Proposed Development's proximity to the Lowther Hill RX/TX and engaged with NERL.

1.8.36 CAP670 *Appendix A to GEN 02* sets out guidance on methodologies for predicting wind turbine AGA impacts. For turbines of the size and proximity of the Proposed Development's to NERL's AGA infrastructure, a Carrier / Interference (**C/I**) assessment is required.

1.8.37 The purpose of the C/I modelling is to identify a "Volume of Interest" in respect of each turbine where:

- the ratio between the wanted signal – C or "carrier" – and the unwanted signal – I or "turbine related interference" falls beneath stated "acceptance criteria" (that is, there is a predicted degradation of signal quality due to turbine related interference); **and**
- there is an operational requirement for aeronautical communications in this potentially impacted airspace, which is informed by an operational impact assessment undertaken by the air traffic controllers who provide an ATS in the general vicinity.

1.8.38 CAP670 *Appendix A to GEN 02* sets out the following acceptance criteria (i.e. where there will be no predicted AGA impact:

- ≥ 20dB C/I for a single turbine or
- ≥ 23dB C/I for the worst single turbine in a windfarm or
- ≥ 14dB C/I for all turbines in a windfarm (assuming all turbines produce in-phase interference)

1.8.39 The Applicant commissioned QQ to undertake AGA C/I modelling at both Very High Frequency (**VHF**) and Ultra High Frequency (**UHF**) frequencies for the NERL AGA infrastructure at Lowther Hill. QQ has previously been involved in AGA modelling and trials. Trials at the North Hoyle Offshore Wind Farm undertaken by the Maritime and Coastguard Agency in conjunction with the RAF in 2004 and 2005 established in respect of VHF communications impacts, even when the entire wind farm complex was between the helicopter hovering at 50ft and the land-based aerial, there was no apparent degradation of performance in the communications links.[30]

1.8.40 In March 2025 the Applicant supplied NERL with detailed QQ modelling which included an AGA C/I assessment for the Proposed Development, together with operational developments (including Clyde and Clyde Extension wind farms) and other developments in planning. NERL has acknowledged the QQ modelling but has not yet provided any definitive feedback.

1.8.41 The QQ modelling is being refreshed to reflect the design freeze layout, which saw the removal of the turbine locations closest to Lowther Hill, and updated turbine parameters (in particular tower diameter) and will be shared with NERL in due course for discussion.

1.8.42 The Applicant acknowledges that the QQ C/I modelling differs slightly to the methodology set out in CAP670 GEN 02. NERL in a preliminary response to Mackenzie Renewables on the AGA issue in July

[28] https://www.eurocontrol.int/publication/eurocontrol-guidelines-assessing-potential-impact-wind-turbines-surveillance-sensors (accessed March 2026)
[29] Feb 2016 edition https://www.caa.co.uk/publication/download/14561 (accessed June 2026)

[30] Offshore Wind Farm Helicopter Search and Rescue Trials Undertaken at North Hoyle Wind Farm, RAF and MCA, May 2005, available at https://users.ece.utexas.edu/~ling/EU2%20offshore_wind_farm_helicopter_trials.pdf (accessed March 2026)

2025 suggested that the QQ modelling was "*roughly equivalent*" to NERL's initial analysis, "*differing only … in the predicted vertical element of the zone of impact*" and that internal discussions at NERL were exploring moving towards the QQ approach.

1.8.43 The CAA informed Mackenzie Renewables in August 2025 that "*the methodology material in CAP670 GEN 02 is guidance and that within the discussion/negotiations between ANSP's and developers there is no hard and fast rule on the methodology that can be used*." Mackenzie Renewables also understands that the CAA's preference is for suitable modelling to be backed up with real-world evidence to best understand the AGA degradation risk to aircraft in the vicinity of wind farms. The operational turbines around Lowther Hill's AGA infrastructure should provide some real-world evidence of detrimental AGA impacts, if any.

1.8.44 The QQ adopts an acceptance criterion (which QQ term a "protection ratio" or PR) of 20dB per turbine. The area where the C/I is less than the PR is referred to as the "interference impact zone" or **IIZ**. Outside the IIZ, there are no impacts; within the IIZ, there are potential impacts of shadowing (signal reduction) and degradation of voice communications quality. The tower IIZ is a narrow "keyhole" shape extending behind the turbine; the blade IIZ is a hemisphere with a radius of up to 400 m (worst case, UHF) centred on the turbine hub.

1.8.45 In summary, the initial QQ modelling established that:

- the impacts on UHF AGA is greater than VHF AGA
- the worst-case tower IIZ may extend a handful of km behind a turbine, but these zones do not extend significantly in height above ground level
- the worst-case IIZ arising from turbine blades extends up to 400 m from hubs but no blade IIZ extends above 4,000ft amsl

1.8.46 The QQ modelling thus identifies the volumes of airspace in which the C/I ratio **may** fall beneath the acceptance criteria.

1.8.47 The CAA in CAP670 *Appendix A to GEN 02* makes it clear that just because "*predicted C/I ratios … fall below the relevant acceptance criteria [this] will not automatically exclude a development*".

1.8.48 It remains for NERL to complete its safeguarding assessment by determining whether this potentially impacted airspace is airspace in which it has an operational requirement for aeronautical communications, which in turn will be determined by what, if any, ATS NERL provides in that airspace.

1.8.49 As outlined above, NERL is principally concerned with providing an ATS in its controlled airspace, but in doing so, it requires good CNS coverage in the approximately 2,000ft beneath its controlled airspace.

1.8.50 The QQ modelling establishes that any potential AGA impact zones, even worst case, are located below 4,000ft amsl, i.e. beneath NERL's controlled airspace and its lower buffer so not adversely impacting the safety or efficiency of NERL's ATS.

1.8.51 It should also be remembered that within the IIZ, AGA communications may be degraded but may still be sufficient for aviation safety. CAP413[31]: Radiotelephony Manual, Table 12, sets out the readability scale as follows:

Readability Scale	Meaning
1	Unreadable
2	Readable now and then
3	Readable but with difficulty
4	Readable
5	Perfectly readable

1.8.52 In this regard, the impacts from the operational turbines on NERL's AGA, based on the QQ modelling, should allow NERL to provide the CAA and the wind industry with real-world evidence to better understand any AGA degradation risk. The duration as well as extent of any impact is also relevant for the operational assessment of AGA impacts on ATS provided (i.e. how long an aircraft is transiting the IIZs).

1.8.53 The Applicant looks forward to sharing with and engaging with NERL on the revised QQ modelling as it anticipates that any AGA impacts will not be operationally significant for NERL's ATS and will not therefore give rise to an objection.

Low flying and turbine lighting

Regulatory framework for turbine lighting

1.8.54 As the Proposed Development's turbines are over 150m, they will require lighting as en-route obstacles in accordance with Article 222 of the ANO. In addition, the MOD has requirements for infra-red (**IR**) lighting of turbines as set out in the MOD Obstruction Light Guidance. These can be both accommodated in a single lighting scheme.

1.8.55 ANO Article 222(6) enables the CAA to modify the strict application of Article 222. The CAA's current policy with respect to onshore "tall" (150m agl and over) turbine lighting is set out in CAP764 7th edition, which is informed by guidance from ICAO Annex 14 Volume 1 Chapter 6. In summary, the standard "tall" turbine lighting requirements applicable to the Proposed Development are:

- One medium intensity (2000 candela) red light to be placed on the nacelle of the turbine; a second 2000 candela red light serving as an alternate should be provided in case of failure of the operating light.
- At least three (to provide 360-degree coverage) low-intensity Type B lights (32 candela) lights to be provided at an intermediate level of half the nacelle height ± 10 m. This requirement may be omitted with CAA approval.
- All lights to be fitted to show when displayed in all directions without interruption.
- For a group of two or more turbines, lighting to be fitted and operated to identify the corners and periphery of the wind farm although not all perimeter turbines need be lit if the distance between them is less than 900m and/or the turbines are within 200m of the perpendicular line connecting two outer turbines – the key concern is to ensure the perimeter of the wind farm can be recognised. The strict application of this requirement may be disapplied with CAA approval.
- If visibility in all directions from every turbine in a group is more than 5km, the light intensity for any visible light required by ANO Article 222 fitted to a turbine may be reduced to not less than 10% of the minimum peak intensity specified for a light of this type.

[31] See edition 23 – Jan 2021 – available at https://www.caa.co.uk/publication/download/18165 (accessed March 2026)

- If an unlit turbine has an elevation of 10 degrees above the horizontal from a lit turbine, that unlit turbine needs to be lit – none of the Proposed Development's turbines fall under this provision.

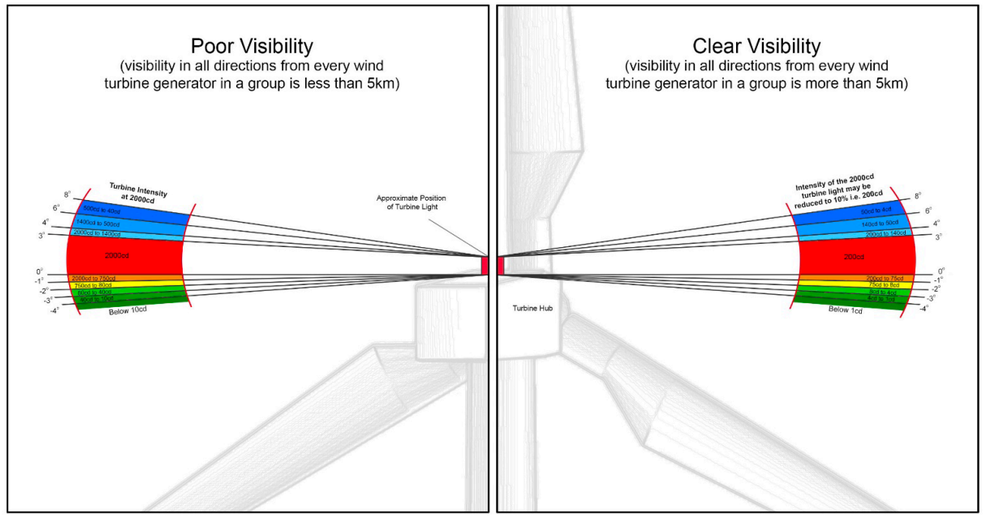
1.8.56 Further mitigation of downwards lighting impacts is inherent in the light distribution for medium and high intensity lights set out in ICAO Annex 14 Table 6-3[32], set out in **Plate 2.3.3** below.

Plate 2.3.3: ICAO Annex 14 Table 6-3

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)
200 000	200 000	150 000	75 000	3°	75 000	250 000	112 500	7 500	7°	75 000
100 000	100 000	75 000	37 500	3°	37 500	125 000	56 250	3 750	7°	37 500
20 000	20 000	15 000	7 500	3°	7 500	25 000	11 250	750	N/A	N/A
2 000	2 000	1 500	750	3°	750	2 500	1 125	75	N/A	N/A

1.8.57 A diagrammatic interpretation of these minimum ICAO requirements for 2000 candela lights in good (5km) and poor (<5km) visibility are illustrated in **Plate 2.3.4** below provided by light manufacturer LuxSolar.

Plate 2.3.4: Diagrammatic Interpretation of Minimum ICAO Requirements



1.8.58 As noted above, the CAA retains discretion to further modify lighting requirements where satisfied that aviation safety is preserved. This is known as a reduced lighting scheme. Reduced lighting schemes usually entail the omission of tower lights and the reduction in number of visible periphery lights. The CAA has granted reduced lighting schemes for the various developments throughout Scotland. The Applicant approached the CAA for a reduced lighting scheme as outlined in the next section, and the CAA has approved this.

1.8.59 Finally, CAP764 7th edition also sets out requirements for Aircraft Detection Lighting Systems (**ADLS**) if ADLS are required to further reduce night landscape and visual impacts of turbine lighting.

1.8.60 The MOD has specific requirements for IR lights to be installed on periphery turbines of windfarms. IR lights are not visible to the human eye but are detectable by aircraft / pilots equipped with Night Vision Devices / Googles (**NVD/NVG**). It is now industry standard for MOD-compliant IR lights to be installed on periphery turbines. The visible and IR lighting of the Proposed Development should address low flying concerns of the MOD.

1.8.61 In addition to MOD aircraft being NVD/NVG capable, Coastguard, Helicopter Emergency Medical Services and Police operators also use NVD/NVG.

CAA approved reduced lighting scheme for the Proposed Development

1.8.62 The CAA has approved the following lighting scheme for the Proposed Development (see **Technical Appendix 1.1: Consultation Register, EIAR Volume 4**):

- Combination ANO Article 222 2000 candela / MOD-compliant IR nacelle lights on turbines 1, 3, 5, 6, 8, 9, 11, 16, 20 and 21
- MOD-compliant IR only nacelle lights on turbines 2, 10, 13 and 19
- No lights on turbines 4, 7, 12, 14, 15, 17 and 18 (all comprising turbines inside the Proposed Development's periphery)
- No tower lights
- Visible lights will be dimmed in good visibility (>5km visibility, 200 candela intensity)
- Visible lights will incorporate the directional intensity parameters set out in ICAO Annex 14

1.8.63 The reduced lighting scheme is shown on **Figure 4.3.1** and has been proposed to address night landscape and visual concerns while seeking to ensure continued aviation safety at night.

1.8.64 It is not currently proposed to seek approval for an ADLS for the Proposed Development.

Turbine charting

1.8.65 In addition to turbine lighting to ensure conspicuity of "tall" en-route obstacles to pilots, all obstacles over 100m agl require notification to the CAA under ANO Article 225A with details regarding the location, height, lighting status, erection timetable, crane utilisation, etc. The CAA will copy such information to the Defence Geographic Centre for inclusion in MOD databases. A current list of such en-route obstacles is found in the Aeronautical Information Publication (**AIP**) ENR5-4. This charting of the Proposed Development should address low flying concerns of the MOD.

1.9 Conclusions

1.9.1 *Aerodromes:* No PSR or IFP issues arising from the Proposed Development are predicted for GLA, GPA or Edinburgh Airport. Stonehill Farm (unlicensed) airstrip lies beyond the 3km consultation distance recommended in CAP764: no impacts are predicted.

1.9.2 *NERL PSR:* The Proposed Development is in RLOS of NERL's Lowther Hill and Cumbernauld PSR, which is likely to result in a detrimental impact on NERL's ATS. The Applicant understands that this PSR impact can be mitigated either by MRT blanking & GLA TS4002 infill or Indra PSR optimisation. The Applicant is prepared to meet reasonably and demonstrably incurred costs of NERL in implementing the selected mitigation in respect of the Proposed Development in line with Circular 4/1998. When current generation of PSR are replaced (c. 2045 in the case of the Indra PSR at Lowther Hill), to extent that PSR remains

[32] ICAO Annex 14 Volume 1: Aerodrome Design and Operations, Nineth edition, July 2022 – available at https://www.bazl.admin.ch/dam/de/sd-web/PzvzqQpFptul/icao_annex_14_aerodromesvolumei-aerodromedesignandoperations.pdf (accessed May 2026)

required for the provision of a civil ATS, the replacement systems should take as their environmental baseline the turbines operational at that date and have windfarm tolerance capabilities.

1.9.3 *NERL SSR:* It is anticipated that the Proposed Development should not cause SSR bearing errors which would detrimentally impact NERL's ATS.

1.9.4 *NERL AGA*: It is anticipated that while the Proposed Development may cause some AGA impacts, this is not predicted to be in airspace such that it would have a detrimental impact on NERL's ATS.

1.9.5 The Proposed Development's turbines will be lit in accordance with ANO Article 222, as modified by the CAA approved reduced lighting scheme outlined above, and MOD IR lighting requirements. This lighting and the charting of the Proposed Development should address low flying concerns of the MOD.