**ELECTRICITY ACT 1989 (SECTION 36 AND SCHEDULE 8)**
**TOWN AND COUNTRY PLANNING ACT 1990 (SECTION 90)**
**THE ELECTRICITY GENERATING STATIONS AND OVERHEAD LINES (INQUIRIES PROCEDURE) (ENGLAND AND WALES) RULES 2007**

**PUBLIC INQUIRY TO CONSIDER SECTION 36 ELECTRICITY ACT 1989 APPLICATIONS BY:**

**(1) STEADINGS WIND FARM LIMITED FOR CONSENT AND DEEMED PLANNING PERMISSION TO CONSTRUCT AND OPERATE A WIND FARM AT KIRKWHELPINGTON, NORTHUMBERLAND (KNOWN AS STEADINGS)**

**(2) AMEC PROJECT INVESTMENTS LIMITED FOR CONSENT AND DEEMED PLANNING PERMISSION TO CONSTRUCT AND OPERATE A WIND FARM AT RAY ESTATE, NORTHUMBERLAND (KNOWN AS RAY WIND FARM)**

**(3) WIND PROSPECT DEVELOPMENTS LIMITED FOR CONSENT AND DEEMED PLANNING PERMISSION TO CONSTRUCT AND OPERATE A WIND FARM AT GREEN RIGG FELL, BIRTLEY, NORTHUMBERLAND (KNOWN AS GREEN RIGG WIND FARM)**

# MARK SPENCER
# PROOF OF EVIDENCE
# IN SUPPORT OF OBJECTION BY MINISTRY OF DEFENCE

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**CONTENTS**

**GLOSSARY OF DEFINED TERMS**

| | |
|---|---|
| ADATS IPT | Air Defence Air Traffic Systems Integrated Project Team |
| AGL | Above Ground Level |
| Air C2 OEU | Air Command and Control Operational Evaluation Unit |
| AMSL | Above Mean Sea Level |
| AOD | Above Ordnance Datum |
| ATC | Air Traffic Control |
| ATS | Air Traffic Services |
| BH | Berry Hill |
| dBm | Power Ratio in decibels measured with respect to 1 milliwatt |
| DWF | Dead Water Fell |
| EGN | East of Grid North |
| GCF | Ground Clutter Filter |
| GR | Green Rigg eindfarm Site |
| IMC | Instrument Meteorological Conditions |
| JMATS | Joint Military Air Traffic Services |
| Km | Kilometre |
| LoS | line of Sight |
| NR | Normal Radar Filter |
| MCF | Moving Clutter Filter |
| MDS | Minimum Discernable Signal |
| MoD | Ministry of Defence |
| PAR | Precision Approach Radar |
| RE | Ray Estates windfarm Site |
| RAF | Royal Air Force |
| RCS | Radar Cross Section |
| ST | Steadings Farm windfarm Site |
| TB | Technical Branch |
| WGS | World Geodetic System |
| WR | Work Request |

**REFERENCES**

A. Work Request (WR) 50177 – Provide Technical Support to Defence Estates on the likely effects the Proposed windfarms may have on ATC radar systems at RAF Spadeadam.

B. The Effect of Wind Turbine Farms on ATC Radar AWC/WAD/72/665/TRIALS dated 10 May 2005.

C. CAP764 – CAA Policy and Guidelines on Wind Turbines Appendix 7

D. DTI Radar Sub Group Meeting Minutes dated 28th March 2008

## INTRODUCTION

1. I, Mark Spencer (ADATS TB3B), became a MoD civil servant in September 1989 under the Telecommunication Technician Officer Training scheme. I have worked in various areas since, including 4 years at the 3rd Line Radar Maintenance facilities at RAF North Luffenham and RAF Sealand. I moved to RAF Henlow TB3 section in August 2000 on promotion to the position of assistant ATC radar systems specialist where I became responsible for the Acceptance Testing of the replacement Precision Approach Radar. In August 2002, on further promotion to my current post as ATC radar systems specialist, I accepted the lead of a small team of Technical Advisors within the Air Defence and Air Traffic Systems Integrated Project Team (ADATS IPT) Technical Branch for ATC Radar Systems, in particular Primary Surveillance Radar (Watchman) and Precision Approach Radar. In all I have over 11 years of experience working specifically on MoD ATC Primary Radar Systems

2. Under Reference A dated 21st November 2007 the ADATS IPT Technical Branch was tasked to complete a technical proof on the possible effects of three proposed windfarms on the Air Traffic Control (ATC) radar systems owned and operated by the Ministry of Defence at and around RAF Spadeadam.

3. This proof only considers the anticipated impact on radar performance of the proposed windfarms and does deal with the operational consequences of the wind turbines, including those resulting from any diminished radar performance. It is the responsibility of MoD Operational Staff to decide if the impact on radar performance is an operational problem or not.

## AIM

4. The aim of this proof is to:

   a. Ascertain the likely effects, both individually and cumulatively, of the proposed windfarms upon the performance of ATC Radar systems at RAF Spadeadam and/or the microwave link between them: this includes an assessment of the likelihood (i.e. probability) of each of the anticipated consequences and an assessment of the extent to which each of those consequences will have upon the ATC radar systems at RAF Spadeadam.

   b. Identify the regions of radar coverage that may be affected for consideration by the relevant ATC authority.

5. The Ministry equipment to be assessed is as follows:

   a. The Watchman radar at Berry Hill
   b. The Watchman radar at Deadwater Fell
   c. The Microwave link between Deadwater Fell, Bolts Law and Berry Hill.

## BACKGROUND INFORMATION ON WATCHMAN PRIMARY SURVEILLANCE RADAR

6. Primary radar operation relies on the reflection of an electro-magnetic pulse from a target of detection. Any structure within the coverage of the radar will return a certain amount of energy in the direction of the radar. The proportion of energy returned depends upon the Radar Cross Sectional Area (RCS) of the structure. Air Traffic Radar systems are designed to maximise detection of aircraft targets against the background of noise and undesirable targets such as reflections off ground surface causing clutter which is otherwise visible on the radar display (often termed clutter)

7. Stationary clutter is attenuated by the radar using the Ground Clutter Filter (GCF). This filter is usually applied over short radar-to-target ranges where ground clutter is predominant. The doppler-shift of the return signal due to the radial movement of a target is used to differentiate between moving targets and stationary clutter. Unfortunately, wind turbine systems generally cause a significant doppler-shift in the frequency of the returned signal because of their large rotating rotor blades. For large blades rotating the return signal will be well within the pass band of the GCF. Wind turbines will therefore be visible as valid targets on the radar display so long as sufficient energy is reflected by the wind turbine corresponding to its Radar Cross Section (RCS). The detection and identification of aircraft targets in and around windfarm regions is therefore likely to become difficult, as there may be nothing to differentiate them on the screen from a turbine.

8. The Watchman radar system comprises a main beam and auxiliary beam. The main beam is used for transmission and reception and is usually elevated to 3° above the horizon. The auxiliary beam is used for reception only. At short target ranges all received signal passes through the auxiliary beam, beyond the beam switch-over range, typically set 16nm, the received signals are passed through the main beam. The main objective of the auxiliary beam is to reduce the amount of ground clutter at short range. The peak of the auxiliary beam is usually elevated to 7° above the horizon so that the antenna gain at low elevation angle is reduced thus reducing ground reflections. For ground based wind turbines, the angle of elevation subtended by the wind turbine to the radar will usually be low compared with an aircraft target. The correspondingly lower antenna gain will give the aircraft some advantage over the wind turbine for detection within the auxiliary beam region. This of course will only be true if the antenna gain to the aircraft plus the RCS of the aircraft substantially exceeds the antenna gain in the direction of the wind turbine plus the RCS of the wind turbine. In this situation the detection threshold of the radar can, in theory, be increased over the windfarm whilst maintaining sensitivity for detection of small targets which reside at elevation angles close to the radar peak of beam. If the wind turbine is located at high elevation angles relative to the radar and its RCS is large, raising the threshold of the radar will not improve the situation and could severely adversely affect radar performance if applied.

9. The radar signal from targets which are situated beyond the windfarm region (from the aspect of the radar) but at similar elevation angles may also be adversely affected by the wind turbines due to radar shadowing; objects which lie beyond the turbines may lie in the radar shadow of the turbine in this region the radar will not be able to receive any reflected energy and will therefore be unable to detect the object.

## THE EFFECTS OF WINDFARMS ON ATC RADAR SYSTEMS

10. In November 2003 the Air Command and Control Operational Evaluation Unit (Air C2 OEU) conducted trials to determine the effects of wind turbine farms on ATC Primary Surveillance Radars. The trial results are detailed in full at Reference B, however for convenience the study's conclusion and recommendations are summarised below:

Conclusion

*The presence of a wind turbine farm in line of sight of a Watchman radar system had a significant impact on its ability to support ATC. This took 2 main forms, obscuration and displayed clutter. These were as a result of the strong radar reflections received from high RCS moving targets, like wind turbines. Due to the nature of the ATC task, it will always be necessary for controllers to honour the presence of a displayed radar return on their screen and treat it as though it was a real aircraft. Displayed clutter is a significant problem. Aircraft manoeuvring in the proximity of an airfield will often operate in IMC and rely on ATC for safe separation from conflicting aircraft. Flying over or in close proximity to a wind turbine can significantly hamper the ability of an ATC operator to maintain the identity of his own aircraft and is also unacceptable in the context of safe provision of Air Traffic Services (ATS). Overall, the presence of a wind turbine farm is not compatible with ATC operations in the vicinity of an airfield. A lateral separation of 5nm should be maintained between wind turbine farms and areas where critical ATC operations take place.*

Recommendations

a. *Planning applications for wind turbine farm development be subject to scrutiny when in line of sight (LoS) of an airfield primary radar, regardless of range but in particular within 30nm of the radar head.*
b. *ATS be limited within 5 nm of the boundary of a wind turbine farm.*
c. *ATC personnel to be advised to select all 3 Watchman channels when operating within 5nm of a wind turbine farm.* (Note1)
d. *Further investigation to be carried out to test the viability of plot extractor-based solutions to the interference effects of wind turbines in ATC environments.* (Note 2)
e. *ATC personnel be made aware that aircraft returns are as likely to fade in front of a wind turbine as behind it (relative to the position of the Watchman radar).*

*Note 1 – The Watchman radar has 3 processing channels; Normal Radar, Ground Clutter filter and Moving Clutter filter. It is possible to enhance a Watchman radar by the installation of a modification known as Range Azimuth Gating (RAG) which allows the outputs from each of the 3 channels to be turned on an off on a range and azimuth basis. The recommendation detailed at Paragraph C ensures that within the windfarm regions all Watchman channel outputs must be enabled to provide maximum probability for the detection of aircraft in that region.*
*Note 2 – Since the completion of the trials as detailed at Reference B the MoD has worked with 2 radar manufactures during a second trial at Clatter and although both manufacturers were successful in reducing the effect windfarms have on ATC radar systems neither was able to provide sufficient mitigation to allow the MOD to accept that they allowed for the safe control of aircraft in the vicinity of wind turbines.*

## WIND TURBINE PROPOSALS

Green Rigg windfarm (GR)

11. These turbines were proposed by Wind Prospects Developments Limited on a site at Hartside, Bellingham. On this particular site there are 18 proposed wind turbines. The tip height of each turbine is 100m AGL with a blade length of 40m (80m rotor diameter), and the turbine hub centres 60m AGL.

Ray Estates windfarm (RE)

12. These turbines were proposed by AMEC Wind on a site is at Humbleton, Haydon Bridge. On this particular site there are 20 proposed wind turbines. The tip height of each turbine is 125m AGL with a blade length of 45m (90m rotor diameter), and the turbine hub centres 80m AGL.

Steadings Farm windfarm (ST)

13. These turbines were proposed by TNEI Services Limited on a site at Steadings Farm, Great Bavington, Co. Durham. On this particular site there are 22 proposed turbines. The tip height of each turbine is 125m AGL with a blade length of 45m (90m rotor diameter), and the turbine hub centres 80m AGL.

## RAF SPADEADAM WATCHMAN RADAR DETAILS

14. The significant parameters of the RAF Spadeadam Radar systems are included at Table 1:

| **Table 1 – RAF Spadeadam Radar Parameters** | | |
|---|---|---|
| | **Radar** | |
| **Parameter** | **Dead Water Fell** | **Berry Hill** |
| Location | 55° 16' 02.0"N<br>02° 35' 28.2"W | 55° 03' 00.8" N<br>02° 33' 12.8"W |
| Height to Base of Tower (AOD) | 568 m | 287.3 m |
| | | |
| **Transmitter** | | |
| Peak Power | 60 kilowatt | 60 kilowatt |
| Frequency Band | 2.7 to 3.05 GHz | 2.7 to 3.05 GHz |
| Pulse Duration | 0.4 µ sec and 20 µsec | 0.4 µ sec and 20 µsec |
| | | |
| **Antenna** | | |
| Polarisation | Circular | Circular |
| Antenna Transmit Gain | 33.8 dB | 33.8 dB |
| Antenna Receive Gain | 33.8 dB | 33.8 dB |
| Antenna Height (AGL) | 16.8 metres | 14 metres |
| Antenna Mechanical Tilt | -1° | 0° |
| Antenna Pattern Shape | Consequent Square | Consequent Square |
| Rotation Rate | 16 RPM | 16 RPM |
| Azimuth Beam Width | 1.4° | 1.4° |

| Table 1 – RAF Spadeadam Radar Parameters (cont) | | |
|---|---|---|
| **Receiver** | | |
| Minimum Range | 0.25 nm | 0.25 nm |
| Maximum Range | 60 nm | 60 nm |
| Receiver Noise | 2.5 dB | 2.5 dB |
| Compressed Pulse Ratio | 50 | 50 |
| False Alarm Rate | 1 in $10^{-6}$ | 1 in $10^{-6}$ |
| Processing Channels | Normal Radar Filter (NR)<br>Ground Clutter Filter (GCF)<br>Moving Clutter Filter (MCF) | Normal Radar Filter (NR)<br>Ground Clutter Filter (GCF)<br>Moving Clutter Filter (MCF) |
| Clutter Cancelation | GCF 40dB<br>MCF 38dB | GCF 40dB<br>MCF 38dB |
| Signal Processing loss | 4.6dB | 4.6dB |
| Main Beam STC Start Range | 2.7 dB | 2.7 dB |
| STC Exponent | R-4 | R-4 |
| STC Run Out Range | <15 nm | <15 nm |
| Minimum Discernable Signal (Note 3) | -121dBm | -121dBm |
| Radar Azimuth Gating Installed (Note 4) | Yes 2 Map system | No |
| Beam Switch | 19.0 nm (de-ragged state) | 16.0 nm |

Note 3 – The Minimum Discernible Signal is defined as the smallest signal at the antenna, which gives a discernable target on the display.

Note 4 – Range Azimuth Gating (RAG) operates by modifying certain parameters to predefined stored values on a Range and Azimuth basis. The functions which may be controlled under RAG are as follows; Beam Switch, Sensitivity Time Control, Pulse Repetition Frequency, Stagger Pattern, GCF Range, NR Channel Inhibit, GCF Channel Inhibit, MCF Channel Inhibit, Frequency selection

## ASSESSMENT OF PROPOSED WINDFARMS ON THE SPADEADAM RADAR SYSTEMS

15. Figure 1 shows the site locations of the RAF Spadeadam Watchman radar systems and each of the proposed windfarm turbines.

Berry Hill radar Line Of Sight Analysis

16. Due to the location of the Berry Hill radar there will be little terrain obscuration between the Berry Hill Watchman radar and each of the proposed windfarm sites. The blue shaded areas shown in Figure 2 represent the areas in which a wind turbine with a maximum tip height of 100 metres AGL (i.e. Green Rig windfarm) would be visible to the radar (i.e. those areas in which the tip of the turbine blade, when at its vertex, would be within the line of sight of the radar). The blue shaded areas shown in figure 3 represent the area in which a wind turbine with a maximum tip height of 125 metres AGL would be visible to the radar (i.e. Ray Estates and Steadings windfarms).

17. From Figures 2 and 3 it is calculated that 100% of the Steadings Farm and Green Rigg wind turbines and approx 35% of the Ray Estate wind turbine blade tips would be in direct line-of-sight from the Berry Hill radar, therefore detailed line-of-sight analysis of each wind turbines is required.

18. Tables 2 to 4 show the result summary from a detailed line-of-sight analysis between the Berry Hill Watchman radar and each of the proposed windfarm turbines. The methodology used for the analysis is detailed at Annex A; each path profile is included at Annex B.

| Table 2: Spadeadam Berry Hill radar to proposed Green Rig Wind Farm | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Turbines** | | | | | | | **Line-of-sight Detail** | | | | | | | | |
| **Number** | **NGR** | | | **Hub** | **Rotor Diameter** | **Tip Height** | **Y/N** | **Visible (m)** | **Accuracy (+/- m)** | **Tip Height for no LOS** | | | **Range (km)** | **Bearing (EGN)** |
| | | | | | | | | | | **Nominal** | **Maximum** | **Minimum** | | |
| 1 | NY | **391784** | **582758** | **60** | **80** | **100** | Y | 79 | 8 | 21 | 29 | 13 | 28.8 | 70.3 |
| 2 | NY | **392335** | **582694** | **60** | **80** | **100** | Y | 86 | 8 | 14 | 22 | 6 | 29.3 | 70.7 |
| 3 | NY | **392345** | **582271** | **60** | **80** | **100** | Y | 88 | 3 | 12 | 15 | 9 | 29.1 | 71.6 |
| 4 | NY | **392015** | **582590** | **60** | **80** | **100** | Y | 86 | 8 | 14 | 22 | 6 | 28.9 | 70.7 |
| 5 | NY | **391508** | **582572** | **60** | **80** | **100** | Y | 81 | 8 | 19 | 27 | 11 | 28.4 | 70.5 |
| 6 | NY | **391067** | **582202** | **60** | **80** | **100** | Y | 101 | 3 | -1 | 2 | -4 | 27.9 | 70.8 |
| 7 | NY | **391428** | **582201** | **60** | **80** | **100** | Y | 98 | 3 | 2 | 5 | -1 | 28.3 | 71.1 |
| 8 | NY | **392006** | **582044** | **60** | **80** | **100** | Y | 90 | 3 | 10 | 13 | 7 | 28.7 | 71.7 |
| 9 | NY | **392646** | **582472** | **60** | **80** | **100** | Y | 86 | 3 | 14 | 17 | 11 | 29.5 | 71.4 |
| 10 | NY | **393008** | **582483** | **60** | **80** | **100** | Y | 76 | 3 | 24 | 27 | 21 | 29.8 | 71.5 |
| 11 | NY | **392579** | **582000** | **60** | **80** | **100** | Y | 65 | 3 | 35 | 38 | 32 | 29.3 | 72.2 |
| 12 | NY | **393133** | **581782** | **60** | **80** | **100** | Y | 75 | 3 | 25 | 28 | 22 | 29.7 | 72.9 |
| 13 | NY | **392786** | **581697** | **60** | **80** | **100** | Y | 75 | 3 | 25 | 28 | 22 | 29.4 | 72.9 |
| 14 | NY | **392425** | **581659** | **60** | **80** | **100** | Y | 84 | 3 | 16 | 19 | 13 | 29.0 | 72.8 |
| 15 | NY | **392398** | **581299** | **60** | **80** | **100** | Y | 81 | 3 | 19 | 22 | 16 | 28.9 | 73.4 |
| 16 | NY | **392039** | **581270** | **60** | **80** | **100** | Y | 69 | 3 | 31 | 34 | 28 | 28.5 | 73.3 |
| 17 | NY | **392001** | **581689** | **60** | **80** | **100** | Y | 82 | 3 | 18 | 21 | 15 | 28.6 | 72.4 |
| 18 | NY | **391658** | **581913** | **60** | **80** | **100** | Y | 82 | 3 | 18 | 21 | 15 | 28.3 | 71.8 |

**Table 3: Spadeadam Berry Hill radar to proposed Ray Estates Wind Farm**

| Turbines | | | | | | | Line-of-sight Detail | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | NGR | | | Hub | Rotor Diameter | Tip Height | Y/N | Visible (m) | Accuracy (+/- m) | Tip Height for no LOS | | | Range (km) | Bearing (EGN) |
| | | | | | | | | | | Nominal | Maximum | Minimum | | |
| 1 | NY | 396794 | 587437 | 80 | 90 | 125 | Y | 41 | 13 | 84 | 97 | 71 | 35.2 | 65.8 |
| 2 | NY | 396317 | 587372 | 80 | 90 | 125 | Y | 48 | 12 | 77 | 89 | 65 | 34.7 | 65.6 |
| 3 | NY | 396171 | 587802 | 80 | 90 | 125 | Y | 28 | 12 | 97 | 109 | 85 | 34.7 | 64.8 |
| 4 | NY | 395591 | 587326 | 80 | 90 | 125 | Y | 40 | 12 | 85 | 97 | 73 | 34.0 | 65.1 |
| 5 | NY | 395075 | 587577 | 80 | 90 | 125 | Y | 31 | 12 | 94 | 106 | 82 | 33.7 | 64.4 |
| 6 | NY | 395011 | 587107 | 80 | 90 | 125 | Y | 19 | 12 | 106 | 118 | 94 | 33.4 | 65.1 |
| 7 | NY | 394667 | 586814 | 80 | 90 | 125 | Y | 4 | 12 | 121 | 133 | 109 | 32.9 | 65.3 |
| 8 | NY | 395409 | 586508 | 80 | 90 | 125 | Y | 43 | 12 | 82 | 94 | 70 | 33.5 | 66.3 |
| 9 | NY | 395958 | 586566 | 80 | 90 | 125 | Y | 68 | 12 | 57 | 69 | 45 | 34.0 | 66.6 |
| 10 | NY | 395031 | 586263 | 80 | 90 | 125 | Y | 31 | 12 | 94 | 106 | 82 | 33.1 | 66.5 |
| 11 | NY | 395358 | 585950 | 80 | 90 | 125 | Y | 51 | 10 | 74 | 84 | 64 | 33.2 | 67.2 |
| 12 | NY | 395482 | 585404 | 80 | 90 | 125 | Y | 44 | 3 | 81 | 84 | 78 | 33.2 | 68.1 |
| 13 | NY | 395041 | 585497 | 80 | 90 | 125 | Y | 56 | 12 | 69 | 81 | 57 | 32.8 | 67.7 |
| 14 | NY | 394513 | 585085 | 80 | 90 | 125 | Y | 70 | 3 | 55 | 58 | 52 | 32.1 | 68.0 |
| 15 | NY | 394971 | 585051 | 80 | 90 | 125 | Y | 49 | 3 | 76 | 79 | 73 | 32.5 | 68.3 |
| 16 | NY | 394483 | 584569 | 80 | 90 | 125 | Y | 55 | 3 | 70 | 73 | 67 | 31.9 | 68.9 |
| 17 | NY | 393889 | 583843 | 80 | 90 | 125 | Y | 72 | 8 | 53 | 61 | 45 | 31.1 | 69.7 |
| 18 | NY | 394089 | 583431 | 80 | 90 | 125 | Y | 75 | 3 | 50 | 53 | 47 | 31.2 | 70.5 |
| 19 | NY | 394543 | 583410 | 80 | 90 | 125 | Y | 82 | 3 | 43 | 46 | 40 | 31.6 | 70.9 |
| 20 | NY | 394977 | 583530 | 80 | 90 | 125 | Y | 76 | 3 | 49 | 52 | 46 | 32.1 | 70.9 |

| Table 4: Spadeadam Berry Hill Radar to proposed Steadings Wind Farm | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Turbines | | | | | | | Line-of-sight Detail | | | | | | | | |
| Number | NGR | | | Hub | Rotor Diameter | Tip Height | Y/N | Visible (m) | Accuracy (+/- m) | Tip Height for no LOS | | | Range (km) | Bearing (EGN) |
| | | | | | | | | | | Nominal | Maximum | Minimum | | |
| 1 | NY | 397742 | 582717 | 80 | 90 | 125 | Y | 47 | 4 | 78 | 82 | 74 | 34.4 | 73.7 |
| 2 | NY | 397358 | 582761 | 80 | 90 | 125 | Y | 45 | 4 | 80 | 84 | 76 | 34.0 | 73.4 |
| 3 | NY | 397479 | 582427 | 80 | 90 | 125 | Y | 65 | 4 | 60 | 64 | 56 | 34.1 | 74.0 |
| 4 | NY | 396959 | 582538 | 80 | 90 | 125 | Y | 37 | 4 | 88 | 92 | 84 | 33.6 | 73.6 |
| 5 | NY | 397061 | 582207 | 80 | 90 | 125 | Y | 55 | 4 | 70 | 74 | 66 | 33.6 | 74.2 |
| 6 | NY | 397546 | 581298 | 80 | 90 | 125 | Y | 100 | 4 | 25 | 29 | 21 | 33.9 | 75.9 |
| 7 | NY | 397413 | 580918 | 80 | 90 | 125 | Y | 110 | 15 | 15 | 30 | 0 | 33.6 | 76.5 |
| 8 | NY | 397921 | 581539 | 80 | 90 | 125 | Y | 88 | 4 | 37 | 41 | 33 | 34.3 | 75.6 |
| 9 | NY | 397995 | 581186 | 80 | 90 | 125 | Y | 110 | 4 | 15 | 19 | 11 | 34.3 | 76.2 |
| 10 | NY | 397162 | 580587 | 80 | 90 | 125 | Y | 103 | 4 | 22 | 26 | 18 | 33.3 | 76.9 |
| 11 | NY | 397570 | 580576 | 80 | 90 | 125 | Y | 117 | 4 | 8 | 12 | 4 | 33.7 | 77.0 |
| 12 | NY | 396973 | 580151 | 80 | 90 | 125 | Y | 97 | 4 | 28 | 32 | 24 | 33.0 | 77.6 |
| 13 | NY | 396871 | 579475 | 80 | 90 | 125 | Y | 95 | 15 | 30 | 45 | 15 | 32.8 | 78.7 |
| 14 | NY | 395323 | 579788 | 80 | 90 | 125 | Y | 108 | 4 | 17 | 21 | 13 | 31.3 | 77.5 |
| 15 | NY | 395690 | 579747 | 80 | 90 | 125 | Y | 97 | 4 | 28 | 32 | 24 | 31.7 | 77.8 |
| 16 | NY | 395895 | 581277 | 80 | 90 | 125 | Y | 99 | 4 | 26 | 30 | 22 | 32.3 | 75.2 |
| 17 | NY | 395504 | 581526 | 80 | 90 | 125 | Y | 94 | 3 | 31 | 34 | 28 | 31.9 | 74.6 |
| 18 | NY | 396621 | 583012 | 80 | 90 | 125 | Y | 45 | 4 | 80 | 84 | 76 | 33.4 | 72.7 |
| 19 | NY | 396271 | 583108 | 80 | 90 | 125 | Y | 62 | 4 | 63 | 67 | 59 | 33.1 | 72.3 |
| 20 | NY | 395238 | 581193 | 80 | 90 | 125 | Y | 94 | 4 | 31 | 35 | 27 | 31.6 | 75.0 |
| 21 | NY | 396708 | 579800 | 80 | 90 | 125 | Y | 96 | 4 | 29 | 33 | 25 | 32.7 | 78.1 |
| 22 | NY | 395278 | 580833 | 80 | 90 | 125 | Y | 97 | 4 | 28 | 32 | 24 | 31.6 | 75.7 |

Deadwater Fell radar line-of-sight Analysis

19. Due to the location of the Deadwater Fell radar there will be little terrain obscuration between the Watchman radar and each of the proposed windfarm sites. The blue shaded areas shown in Figure 4 represent the areas in which a wind turbine with a maximum tip height of 100 metres, or greater, AGL would be visible to the radar (i.e. those areas in which the tip of the turbine blade, when at its vertex, would be within the line-of-sight of the radar).

20. From Figure 4 it is estimated that ***all*** the proposed wind turbine blade tips would be in direct line of sight from the Deadwater Fell radar, therefore detailed line-of-sight analysis of each wind turbines is required.

21. Tables 5 to 7 show the result summary from a detailed line-of-sight analysis between the Dead Water Fell Watchman radar and each of the proposed windfarms. The methodology is the same as that used at paragraph 18; each path profile is displayed at Annex C.

| Table 5: Spadeadam Deadwater Fell radar to proposed Green Rig Wind Farm | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Turbines | | | | | | | Line-of-sight Detail | | | | | | | | | |
| Number | NGR | | | Hub | Rotor Diameter | Tip Height | Y/N | Visible (m) | Accuracy (+/- m) | Tip Height for no LOS | | | Range (km) | Bearing (EGN) |
| | | | | | | | | | | Nominal | Maximum | Minimum | | |
| 1 | NY | 391784 | 582758 | 60 | 80 | 100 | Y | 79 | 3 | 21 | 24 | 18 | 32.6 | 116.2 |
| 2 | NY | 392335 | 582694 | 60 | 80 | 100 | Y | 56 | 3 | 44 | 47 | 41 | 33.1 | 115.9 |
| 3 | NY | 392345 | 582271 | 60 | 80 | 100 | Y | 85 | 3 | 15 | 18 | 12 | 33.3 | 116.6 |
| 4 | NY | 392015 | 582590 | 60 | 80 | 100 | Y | 73 | 3 | 27 | 30 | 24 | 32.9 | 116.3 |
| 5 | NY | 391508 | 582572 | 60 | 80 | 100 | Y | 86 | 3 | 14 | 17 | 11 | 32.4 | 116.8 |
| 6 | NY | 391067 | 582202 | 60 | 80 | 100 | Y | 103 | 3 | -3 | 0 | -6 | 32.2 | 117.7 |
| 7 | NY | 391428 | 582201 | 60 | 80 | 100 | Y | 99 | 3 | 1 | 4 | -2 | 32.6 | 117.4 |
| 8 | NY | 392006 | 582044 | 60 | 80 | 100 | Y | 90 | 3 | 10 | 13 | 7 | 33.1 | 117.2 |
| 9 | NY | 392646 | 582472 | 60 | 80 | 100 | Y | 63 | 3 | 37 | 40 | 34 | 33.5 | 116.0 |
| 10 | NY | 393008 | 582483 | 60 | 80 | 100 | Y | 46 | 3 | 54 | 57 | 51 | 33.8 | 115.7 |
| 11 | NY | 392579 | 582000 | 60 | 80 | 100 | Y | 77 | 3 | 23 | 26 | 20 | 33.7 | 116.8 |
| 12 | NY | 393133 | 581782 | 60 | 80 | 100 | Y | 80 | 3 | 20 | 23 | 17 | 34.3 | 116.6 |
| 13 | NY | 392786 | 581697 | 60 | 80 | 100 | Y | 87 | 3 | 13 | 16 | 10 | 34.0 | 117.1 |
| 14 | NY | 392425 | 581659 | 60 | 80 | 100 | Y | 95 | 3 | 5 | 8 | 2 | 33.7 | 117.4 |
| 15 | NY | 392398 | 581299 | 60 | 80 | 100 | Y | 98 | 3 | 2 | 5 | -1 | 33.8 | 118.0 |
| 16 | NY | 392039 | 581270 | 60 | 80 | 100 | Y | 79 | 3 | 21 | 24 | 18 | 33.5 | 118.3 |
| 17 | NY | 392001 | 581689 | 60 | 80 | 100 | Y | 92 | 3 | 8 | 11 | 5 | 33.3 | 117.7 |
| 18 | NY | 391658 | 581913 | 60 | 80 | 100 | Y | 92 | 3 | 8 | 11 | 5 | 32.9 | 117.7 |

| Table 6: Spadeadam Deadwater Fell radar to proposed Steadings Wind Farm | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Turbines** | | | | | | | **Line-of-sight Detail** | | | | | | | | |
| **Number** | **NGR** | | | **Hub** | **Rotor Diameter** | **Tip Height** | **Y/N** | **Visible (m)** | **Accuracy (+/- m)** | **Tip Height for no LOS** | | | **Range (km)** | **Bearing (EGN)** |
| | | | | | | | | | | **Nominal** | **Maximum** | **Minimum** | | |
| 1 | NY | 397742 | 582717 | 80 | 90 | 125 | Y | 87 | 3 | 38 | 41 | 35 | 38.1 | 112.3 |
| 2 | NY | 397358 | 582761 | 80 | 90 | 125 | Y | 83 | 3 | 42 | 45 | 39 | 37.7 | 112.5 |
| 3 | NY | 397479 | 582427 | 80 | 90 | 125 | Y | 67 | 3 | 58 | 61 | 55 | 37.9 | 112.8 |
| 4 | NY | 396959 | 582538 | 80 | 90 | 125 | Y | 35 | 3 | 90 | 93 | 87 | 37.4 | 113.0 |
| 5 | NY | 397061 | 582207 | 80 | 90 | 125 | Y | 43 | 4 | 82 | 86 | 78 | 37.6 | 113.4 |
| 6 | NY | 397546 | 581298 | 80 | 90 | 125 | Y | 64 | 3 | 61 | 64 | 58 | 38.4 | 114.4 |
| 7 | NY | 397413 | 580918 | 80 | 90 | 125 | Y | 53 | 4 | 72 | 76 | 68 | 38.5 | 115.0 |
| 8 | NY | 397921 | 581539 | 80 | 90 | 125 | Y | 85 | 3 | 40 | 43 | 37 | 38.7 | 113.8 |
| 9 | NY | 397995 | 581186 | 80 | 90 | 125 | Y | 79 | 3 | 46 | 49 | 43 | 38.9 | 114.2 |
| 10 | NY | 397162 | 580587 | 80 | 90 | 125 | Y | 45 | 4 | 80 | 84 | 76 | 38.4 | 115.6 |
| 11 | NY | 397570 | 580576 | 80 | 90 | 125 | Y | 54 | 4 | 71 | 75 | 67 | 38.7 | 115.3 |
| 12 | NY | 396973 | 580151 | 80 | 90 | 125 | Y | 63 | 4 | 62 | 66 | 58 | 38.4 | 116.3 |
| 13 | NY | 396871 | 579475 | 80 | 90 | 125 | Y | 76 | 4 | 49 | 53 | 45 | 38.6 | 117.3 |
| 14 | NY | 395323 | 579788 | 80 | 90 | 125 | Y | 86 | 3 | 39 | 42 | 36 | 37.1 | 117.9 |
| 15 | NY | 395690 | 579747 | 80 | 90 | 125 | Y | 78 | 3 | 47 | 50 | 44 | 37.5 | 117.7 |
| 16 | NY | 395895 | 581277 | 80 | 90 | 125 | Y | 49 | 4 | 76 | 80 | 72 | 36.9 | 115.4 |
| 17 | NY | 395504 | 581526 | 80 | 90 | 125 | Y | 51 | 3 | 74 | 77 | 71 | 36.5 | 115.3 |
| 18 | NY | 396621 | 583012 | 80 | 90 | 125 | Y | 63 | 3 | 62 | 65 | 59 | 36.9 | 112.6 |
| 19 | NY | 396271 | 583108 | 80 | 90 | 125 | Y | 81 | 3 | 44 | 47 | 41 | 36.5 | 112.6 |
| 20 | NY | 395238 | 581193 | 80 | 90 | 125 | Y | 57 | 3 | 68 | 71 | 65 | 36.4 | 116.0 |
| 21 | NY | 396708 | 579800 | 80 | 90 | 125 | Y | 85 | 3 | 40 | 43 | 37 | 38.3 | 116.9 |
| 22 | NY | 395278 | 580833 | 80 | 90 | 125 | Y | 80 | 3 | 45 | 48 | 42 | 36.6 | 116.5 |

| Table 7: Spadeadam Deadwater Fell radar to proposed Ray Estates Wind Farm | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Turbines | | | | | | | Line-of-sight Detail | | | | | | | | |
| Number | NGR | | | Hub | Rotor Diameter | Tip Height | Y/N | Visible (m) | Accuracy (+/- m) | Tip Height for no LOS | | | Range (km) | Bearing (EGN) |
| | | | | | | | | | | Nominal | Maximum | Minimum | | |
| 1 | NY | 396794 | 587437 | 80 | 90 | 125 | Y | 124 | 3 | 1 | 4 | -2 | 35.6 | 105.8 |
| 2 | NY | 396317 | 587372 | 80 | 90 | 125 | Y | 122 | 3 | 3 | 6 | 0 | 35.2 | 106.2 |
| 3 | NY | 396171 | 587802 | 80 | 90 | 125 | Y | 115 | 3 | 10 | 13 | 7 | 34.9 | 105.6 |
| 4 | NY | 395591 | 587326 | 80 | 90 | 125 | Y | 115 | 3 | 10 | 13 | 7 | 34.5 | 106.5 |
| 5 | NY | 395075 | 587577 | 80 | 90 | 125 | Y | 106 | 3 | 19 | 22 | 16 | 33.9 | 106.4 |
| 6 | NY | 395011 | 587107 | 80 | 90 | 125 | Y | 76 | 3 | 49 | 52 | 46 | 34.0 | 107.2 |
| 7 | NY | 394667 | 586814 | 80 | 90 | 125 | Y | 105 | 3 | 20 | 23 | 17 | 33.7 | 107.9 |
| 8 | NY | 395409 | 586508 | 80 | 90 | 125 | Y | 129 | 3 | -4 | -1 | -7 | 34.6 | 108.0 |
| 9 | NY | 395958 | 586566 | 80 | 90 | 125 | Y | 124 | 3 | 1 | 4 | -2 | 35.1 | 107.6 |
| 10 | NY | 395031 | 586263 | 80 | 90 | 125 | Y | 127 | 3 | -2 | 1 | -5 | 34.3 | 108.6 |
| 11 | NY | 395358 | 585950 | 80 | 90 | 125 | Y | 128 | 3 | -3 | 0 | -6 | 34.7 | 108.9 |
| 12 | NY | 395482 | 585404 | 80 | 90 | 125 | Y | 112 | 3 | 13 | 16 | 10 | 35.0 | 109.6 |
| 13 | NY | 395041 | 585497 | 80 | 90 | 125 | Y | 126 | 3 | -1 | 2 | -4 | 34.5 | 109.7 |
| 14 | NY | 394513 | 585085 | 80 | 90 | 125 | Y | 112 | 4 | 13 | 17 | 9 | 34.2 | 110.7 |
| 15 | NY | 394971 | 585051 | 80 | 90 | 125 | Y | 103 | 4 | 22 | 26 | 18 | 34.6 | 110.5 |
| 16 | NY | 394483 | 584569 | 80 | 90 | 125 | Y | 100 | 4 | 25 | 29 | 21 | 34.4 | 111.5 |
| 17 | NY | 393889 | 583843 | 80 | 90 | 125 | Y | 67 | 3 | 58 | 61 | 55 | 34.1 | 113.0 |
| 18 | NY | 394089 | 583431 | 80 | 90 | 125 | Y | 78 | 3 | 47 | 50 | 44 | 34.4 | 113.5 |
| 19 | NY | 394543 | 583410 | 80 | 90 | 125 | Y | 67 | 3 | 58 | 61 | 55 | 34.9 | 113.3 |
| 20 | NY | 394977 | 583530 | 80 | 90 | 125 | Y | 73 | 3 | 52 | 55 | 49 | 35.2 | 112.7 |

## Impact Assessment of Proposed Wind Turbines on Berry Hill radar

22. To identify the perceived impact each of the proposed windfarms has on the Berry Hill radar the assessment methodology as detailed at Reference B was used. The methodology for the assessment, which has been endorsed by the Civilian Aviation Authority, is given in detailed at Reference B. For convenience, the general principles are summarised below:

*This assessment method relies upon the availability of radar cross-sectional (RCS) data for the static (tower, nacelle etc) and moving (rotor blades) elements of the proposed wind turbines(s). It should be noted, that where these figures are not available, data derived from a generic wind turbine could be substituted. Similarity, it is assumed that radar vertical aperture antenna patterns would be available.*

*This method also relies on the availability of a propagation prediction tool with a Digital Terrain mapping database of good resolution (i.e. 50 m or better)*

*A key objective of this assessment method is to ensure that it is open and transparent. With the above pre-requisites in place, it is envisaged that anyone could enter the relevant data into an agreed proforma or spreadsheet and obtain an initial assessment as to the visibility of a wind turbine development upon a particular primary radar station.*

23. ADTI HTZ Warfare is a software package, that meets the requirement of Reference B Appendix 7. This tool has been utilised by the ADATS IPT Technical Branch for the past eight years to predict Watchman radar Volume of Coverage during the survey phase of Watchman Installation and its performance has been validated during the Commissioning Flight Trials phase at a number of units utilising both dedicated Flight Trials Aircraft and Targets of Opportunity.

24. The turbines from each proposed windfarm (Green Rig, Steadings and Ray Estates) have been assessed using HTZ Warfare and their predicted Signal Strength presented to the Berry Hill Antenna calculated; the results obtained are shown at tables 8, 9 and 10 respectively.

**Table 8: Green Rig Wind Farm Turbine Signal Strength to Berry Hill radar**

| Number | NGR | | | Static Structure Predicted Signal Strength (dBm) | Static Structure Greater than Watchman MDS (Y/N) | Moving Structure Predicted Signal Strength (dBm) | Moving Structure Greater than Watchman MDS (Y/N) |
|---|---|---|---|---|---|---|---|
| 1 | NY | 391784 | 582758 | -116.6 | Yes | -113.4 | Yes |
| 2 | NY | 392335 | 582694 | -117.6 | Yes | -111.9 | Yes |
| 3 | NY | 392345 | 582271 | -109.9 | Yes | -109.2 | Yes |
| 4 | NY | 392015 | 582590 | -118.9 | Yes | -112.0 | Yes |
| 5 | NY | 391508 | 582572 | -117.8 | Yes | -111.5 | Yes |
| 6 | NY | 391067 | 582202 | -109.3 | Yes | -108.2 | Yes |
| 7 | NY | 391428 | 582201 | -109.9 | Yes | -108.6 | Yes |
| 8 | NY | 392006 | 582044 | -110.1 | Yes | -109.1 | Yes |
| 9 | NY | 392646 | 582472 | -111.4 | Yes | -109.9 | Yes |
| 10 | NY | 393008 | 582483 | -114.9 | Yes | -111.4 | Yes |
| 11 | NY | 392579 | 582000 | -112.2 | Yes | -110.2 | Yes |
| 12 | NY | 393133 | 581782 | -110.5 | Yes | -109.7 | Yes |
| 13 | NY | 392786 | 581697 | -111.0 | Yes | -109.6 | Yes |
| 14 | NY | 392425 | 581659 | -109.0 | Yes | -109.1 | Yes |
| 15 | NY | 392398 | 581299 | -110.7 | Yes | -109.9 | Yes |
| 16 | NY | 392039 | 581270 | -109.9 | Yes | -108.9 | Yes |
| 17 | NY | 392001 | 581689 | -108.7 | Yes | -108.7 | Yes |
| 18 | NY | 391658 | 581913 | -109.1 | Yes | -108.7 | Yes |

25. The Berry Hill Watchman radar has a Minimum Discernable Signal threshold of -121 dBm. Accordingly based on the results at Table 8, it is apparent that the Signal Strengths from the moving structure of ***all*** 18 Green Rig Turbines are such that they would be detected by the radar and displayed on the operators' display.

| Table 9: Steadings Wind Farm Turbine Signal Strength to Berry Hill radar | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number | NGR | | | Static Structure Predicted Signal Strength (dBm) | Static Structure Greater than Watchman MDS (Y/N) | Moving Structure Predicted Signal Strength (dBm) | Moving Structure Greater than Watchman MDS (Y/N) |
| 1 | NY | 397742 | 582717 | -112.6 | Yes | -99.2 | Yes |
| 2 | NY | 397358 | 582761 | -114.2 | Yes | -99.2 | Yes |
| 3 | NY | 397479 | 582427 | -100.8 | Yes | -97.3 | Yes |
| 4 | NY | 396959 | 582538 | -126.1 | No | -100.4 | Yes |
| 5 | NY | 397061 | 582207 | -104.8 | Yes | -97.9 | Yes |
| 6 | NY | 397546 | 581298 | -98.9 | Yes | -97.2 | Yes |
| 7 | NY | 397413 | 580918 | -99.2 | Yes | -96.7 | Yes |
| 8 | NY | 397921 | 581539 | -94.1 | Yes | -95.4 | Yes |
| 9 | NY | 397995 | 581186 | -98.5 | Yes | -97.4 | Yes |
| 10 | NY | 397162 | 580587 | -101.6 | Yes | -98.1 | Yes |
| 11 | NY | 397570 | 580576 | -98.5 | Yes | -97.1 | Yes |
| 12 | NY | 396973 | 580151 | -99.5 | Yes | -97.1 | Yes |
| 13 | NY | 396871 | 579475 | -99.6 | Yes | -97.4 | Yes |
| 14 | NY | 395323 | 579788 | -96.8 | Yes | -95.4 | Yes |
| 15 | NY | 395690 | 579747 | -97.3 | Yes | -95.7 | Yes |
| 16 | NY | 395895 | 581277 | -91.4 | Yes | 94.1 | Yes |
| 17 | NY | 395504 | 581526 | -92.0 | Yes | -93.9 | Yes |
| 18 | NY | 396621 | 583012 | -116.5 | Yes | -99.3 | Yes |
| 19 | NY | 396271 | 583108 | -98.9 | Yes | -96.1 | Yes |
| 20 | NY | 395238 | 581193 | -91.8 | Yes | -93.7 | Yes |
| 21 | NY | 396708 | 579800 | -98.9 | Yes | -96.8 | Yes |
| 22 | NY | 395278 | 580833 | -96.2 | Yes | -95.3 | Yes |

26. The Berry Hill Watchman radar has a Minimum Discernable Signal threshold of -121 dBm. Accordingly based on the results at Table 9, it is apparent that the Signal Strengths from the moving structure of ***all*** 22 Steadings Turbines are such that they would be detected by the radar and displayed on the operators' display.

| Table 10: Ray Estates Wind Farm Turbine Signal Strength to Berry Hill radar | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number | NGR | | | Static Structure Predicted Signal Strength (dBm) | Static Structure Greater than Watchman MDS (Y/N) | Moving Structure Predicted Signal Strength (dBm) | Moving Structure Greater than Watchman MDS (Y/N) |
| 1 | NY | 396794 | 587437 | -115.7 | Yes | -101.9 | Yes |
| 2 | NY | 396317 | 587372 | -114.1 | Yes | -101.5 | Yes |
| 3 | NY | 396171 | 587802 | -116.6 | Yes | -101.8 | Yes |
| 4 | NY | 395591 | 587326 | -115.0 | Yes | -101.3 | Yes |
| 5 | NY | 395075 | 587577 | -115.8 | Yes | -101.1 | Yes |
| 6 | NY | 395011 | 587107 | -118.9 | Yes | 101.3 | Yes |
| 7 | NY | 394667 | 586814 | -118.9 | Yes | -101.1 | Yes |
| 8 | NY | 395409 | 586508 | -111.3 | Yes | -100.5 | Yes |
| 9 | NY | 395958 | 586566 | -108.1 | Yes | -99.9 | Yes |
| 10 | NY | 395031 | 586263 | -115.9 | Yes | -96.3 | Yes |
| 11 | NY | 395358 | 585950 | -111.5 | Yes | -100.2 | Yes |
| 12 | NY | 395482 | 585404 | -116.5 | Yes | -100.6 | Yes |
| 13 | NY | 395041 | 585497 | -110.5 | Yes | -99.7 | Yes |
| 14 | NY | 394513 | 585085 | -111.8 | Yes | -99.5 | Yes |
| 15 | NY | 394971 | 585051 | -111.5 | Yes | -99.7 | Yes |
| 16 | NY | 394483 | 584569 | -109.4 | Yes | -99.0 | Yes |
| 17 | NY | 393889 | 583843 | -103.2 | Yes | -97.1 | Yes |
| 18 | NY | 394089 | 583431 | -103.3 | Yes | -97.2 | Yes |
| 19 | NY | 394543 | 583410 | -100.5 | Yes | -96.8 | Yes |
| 20 | NY | 394977 | 583530 | -103.0 | Yes | -97.3 | Yes |

27. The Berry Hill Watchman radar has a Minimum Discernable Signal threshold of -121 dBm. Accordingly based on the results at Table 10, it is apparent that the Signal Strengths from the moving structure of ***all*** 20 Ray Estates Turbines are such that they would be detected by the radar and displayed on the operators' display.

Detailed Analysis of proposed Wind Turbines on the Deadwater Fell radar

28. The turbines from each proposed windfarm (Green Rig, Steadings and Ray Estates) have been assessed using HTZ Warfare and their predicted Signal Strength presented to the Dead Water Fell Antenna calculated, the results obtained are shown at tables 11, 12 and 13 respectively.

| Table 11: Green Rig Wind Farm Turbine Signal Strength to Dead Water Fell radar | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number | NGR | | | Static Structure Predicted Signal Strength (dBm) | Static Structure Greater than Watchman MDS (Y/N) | Moving Structure Predicted Signal Strength (dBm) | Moving Structure Greater than Watchman MDS (Y/N) |
| 1 | NY | 391784 | 582758 | -107.0 | Yes | -107.0 | Yes |
| 2 | NY | 392335 | 582694 | -110.2 | Yes | -107.5 | Yes |
| 3 | NY | 392345 | 582271 | -106.7 | Yes | -107.4 | Yes |
| 4 | NY | 392015 | 582590 | -108.2 | Yes | -107.3 | Yes |
| 5 | NY | 391508 | 582572 | -106.1 | Yes | -107.0 | Yes |
| 6 | NY | 391067 | 582202 | -105.1 | Yes | -106.9 | Yes |
| 7 | NY | 391428 | 582201 | -105.2 | Yes | -107.0 | Yes |
| 8 | NY | 392006 | 582044 | -106.4 | Yes | -107.4 | Yes |
| 9 | NY | 392646 | 582472 | -109.6 | Yes | -107.6 | Yes |
| 10 | NY | 393008 | 582483 | -134.8 | No | -111.6 | Yes |
| 11 | NY | 392579 | 582000 | -109.0 | Yes | -107.8 | Yes |
| 12 | NY | 393133 | 581782 | -108.3 | Yes | -107.9 | Yes |
| 13 | NY | 392786 | 581697 | -107.7 | Yes | -107.9 | Yes |
| 14 | NY | 392425 | 581659 | -106.2 | Yes | -107.6 | Yes |
| 15 | NY | 392398 | 581299 | -106.7 | Yes | -107.7 | Yes |
| 16 | NY | 392039 | 581270 | -107.5 | Yes | -107.5 | Yes |
| 17 | NY | 392001 | 581689 | 106.3 | Yes | -107.5 | Yes |
| 18 | NY | 391658 | 581913 | -106.2 | Yes | -107.3 | Yes |

29. The Dead Water Fell Watchman radar has a Minimum Discernable Signal threshold of -121 dBm. Accordingly based on the results at Table 11, it is apparent that the Signal Strengths from the moving structure of ***all*** 18 Green Rig Turbines are such that they would be detected by the radar and displayed on the operators' display.

| Table 12: Steadings Wind Farm Turbine Signal Strength to Dead Water Fell radar | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number | NGR | | | Static Structure Predicted Signal Strength (dBm) | Static Structure Greater than Watchman MDS (Y/N) | Moving Structure Predicted Signal Strength (dBm) | Moving Structure Greater than Watchman MDS (Y/N) |
| 1 | NY | 397742 | 582717 | **-99.9** | **Yes** | **-104.1** | **Yes** |
| 2 | NY | 397358 | 582761 | **-100.2** | **Yes** | **-104.0** | **Yes** |
| 3 | NY | 397479 | 582427 | **-105.7** | **Yes** | **-105.3** | **Yes** |
| 4 | NY | 396959 | 582538 | **-131.7** | **No** | **-108.6** | **Yes** |
| 5 | NY | 397061 | 582207 | **-105.7** | **Yes** | **-105.6** | **Yes** |
| 6 | NY | 397546 | 581298 | **-105.9** | **Yes** | **-105.5** | **Yes** |
| 7 | NY | 397413 | 580918 | **-110.1** | **Yes** | **-106.7** | **Yes** |
| 8 | NY | 397921 | 581539 | **-101.7** | **Yes** | **-101.7** | **Yes** |
| 9 | NY | 397995 | 581186 | **-105.5** | **Yes** | **-104.5** | **Yes** |
| 10 | NY | 397162 | 580587 | **-124.5** | **No** | **-108.6** | **Yes** |
| 11 | NY | 397570 | 580576 | **-113.2** | **Yes** | **-107.4** | **Yes** |
| 12 | NY | 396973 | 580151 | **-107.2** | **Yes** | **-106.0** | **Yes** |
| 13 | NY | 396871 | 579475 | **-101.3** | **Yes** | **-104.5** | **Yes** |
| 14 | NY | 395323 | 579788 | **-101.4** | **Yes** | **-103.7** | **Yes** |
| 15 | NY | 395690 | 579747 | **-109.6** | **Yes** | **-103.7** | **Yes** |
| 16 | NY | 395895 | 581277 | **-109.6** | **Yes** | **-106.2** | **Yes** |
| 17 | NY | 395504 | 581526 | **-120.3** | **Yes** | **-107.0** | **Yes** |
| 18 | NY | 396621 | 583012 | **-105.3** | **Yes** | **-104.9** | **Yes** |
| 19 | NY | 396271 | 583108 | **-100.6** | **Yes** | **-103.4** | **Yes** |
| 20 | NY | 395238 | 581193 | **-104.4** | **Yes** | **-104.4** | **Yes** |
| 21 | NY | 396708 | 579800 | **-101.9** | **Yes** | **-104.2** | **Yes** |
| 22 | NY | 395278 | 580833 | **-100.9** | **Yes** | **-103.4** | **Yes** |

30. The Dead Water Fell Watchman radar has a Minimum Discernable Signal threshold of -121 dBm. Accordingly based on the results at Table 12, it is apparent that the Signal Strengths from the moving structure of ***all*** 22 Steadings Turbines are such that they would be detected by the radar and displayed on the operators' display.

| Table 13: Ray Estates Wind Farm Turbine Signal Strength to Dead Water Fell radar | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number | NGR | | | Static Structure Predicted Signal Strength (dBm) | Static Structure Greater than Watchman MDS (Y/N) | Moving Structure Predicted Signal Strength (dBm) | Moving Structure Greater than Watchman MDS (Y/N) |
| 1 | NY | 396794 | 587437 | -103.8 | Yes | -108.2 | Yes |
| 2 | NY | 396317 | 587372 | -103.8 | Yes | -107.8 | Yes |
| 3 | NY | 396171 | 587802 | -103.9 | Yes | -107.6 | Yes |
| 4 | NY | 395591 | 587326 | -104.0 | Yes | -107.4 | Yes |
| 5 | NY | 395075 | 587577 | -104.0 | Yes | -107.1 | Yes |
| 6 | NY | 395011 | 587107 | -107.3 | Yes | -107.7 | Yes |
| 7 | NY | 394667 | 586814 | -105.7 | Yes | -107.5 | Yes |
| 8 | NY | 395409 | 586508 | -103.8 | Yes | -107.7 | Yes |
| 9 | NY | 395958 | 586566 | -103.3 | Yes | -107.5 | Yes |
| 10 | NY | 395031 | 586263 | -105.6 | Yes | -107.7 | Yes |
| 11 | NY | 395358 | 585950 | -106.4 | Yes | -107.6 | Yes |
| 12 | NY | 395482 | 585404 | -107.4 | Yes | -108.1 | Yes |
| 13 | NY | 395041 | 585497 | -106.0 | Yes | -107.5 | Yes |
| 14 | NY | 394513 | 585085 | -106.0 | Yes | -107.6 | Yes |
| 15 | NY | 394971 | 585051 | -107.9 | Yes | -108.2 | Yes |
| 16 | NY | 394483 | 584569 | -105.9 | Yes | -107.7 | Yes |
| 17 | NY | 393889 | 583843 | -109.4 | Yes | -108.0 | Yes |
| 18 | NY | 394089 | 583431 | -109.3 | Yes | -108.1 | Yes |
| 19 | NY | 394543 | 583410 | -108.3 | Yes | -108.3 | Yes |
| 20 | NY | 394977 | 583530 | -108.3 | Yes | -108.3 | Yes |

31. The Berry Hill Watchman radar has a Minimum Discernable Signal threshold of -121 dBm. Accordingly based on the results at Table 13, it is apparent that the Signal Strengths from the moving structure of ***all*** 20 Ray Estates Turbines are such that they would be detected by the radar and displayed on the operators display.

## ASSESSMENT OF PROPOSED WINDFARMS ON THE MICROWAVE LINK BETWEEN DEADWATER FELL AND BERRY HILL

32. Radar data from the Watchman radar at Deadwater Fell is sent to Berry Hill ATC via a microwave link which uses a repeater situated at Bolt's Law. From Figure 1 it is clear that the proposed windfarms will not impinge on these paths and the separation distances between the paths and the windfarms will ensure that no interference effects will be apparent.

## ASSESSMENT OF OTHER WINDFARMS WITHIN LINE-OF-SIGHT TO RAF SPADEADAM WATCHMAN RADAR SYSTEMS

33. Included at Annex D is a detailed assessment of all other known windfarms (either operation, under construction, planning consented or in planning) which have line-of-sight to either or both of the RAF Watchman Radar systems.

## POSSIBLE WINDFARM MITIGATIONS

34. The following are the only known, proven methods by which it would be possible to remove or to reduce the signals returns from the windfarm turbines from appearing on the operators' screens.

35. The first method would be to raise the Watchman radar detection threshold above that at which it has been presently set. I would point out that the current detection threshold level has been used for many years, and was deployed after much experimentation in order to ascertain the optimal level. In order to prevent signal returns from wind turbines being displayed upon the radar operators' screens by raising the detection threshold (i.e. by raising the level at which a signal return produces a display upon the operators' screens) the receiver would need to be desensitised by at least 29 dB. The desensitisation would apply to all return signals, regardless of origin. As indicated above, the detection threshold has been currently set so as to optimise the display of unwanted return signals whilst not displaying unwanted signals. Desensitisation by 29 dB would result in many **wanted** signals not being displayed upon the operators' screen. In my professional assessment desensitisation by 29 dB would have a very severe adverse effect upon the efficacy of each of the two radars serving RAF Spadeadam: namely, large numbers of return signals that are essential for the effective operation of the facility would not be displayed upon the radar operators' screen.

36. The second method would be to utilise an "in-fill" radar. This would involve taking data from one or more existing remote radar systems that have a base of radar coverage in and around the windfarm region and that meets the operational requirement of RAF Spadeadam but that does not have direct line of sight to the proposed windfarms (so that they are not afflicted by above threshold returns from turbines). The ATC Controller would have procedures in place so that the signal returns for these areas from the two Watchman radars would be ignored and, instead, the data would be supplied by the in-fill radars. This would be "added" to the system to produce a composite picture display on the controllers' screens. Self evidently, the efficacy of the system requires that the in-fill radars not be afflicted by above threshold returns from turbines.

37. My investigation into such potential ATC radar systems within vicinity of the proposed windfarms yielded the radar systems as displayed at Figure 5. From Figure 5 the following systems were identified as potential in-fill radar systems:

| Radar location | Latitude | Longitude | Radar Type | Rotation Rate |
|---|---|---|---|---|
| Edinburgh | 55° 57' North | 03° 20' West | Watchman | 15 RPM |
| Great Dun Fell | 54° 41' North | 02° 27' West | HAS/SREM5 | 7.5 RPM |
| RAF Leeming | 54° 18' North | 01° 33' West | Watchman | 16 RPM |
| Lowther Hill | 54° 23' North | 03° 45' West | Routeman | 10 RPM |
| Newcastle | 55° 02' North | 01°42' West | Marconi (S511) | 15 RPM |
| Teesside | 54° 31' North | 01° 25 West | Watchman | 15 RPM |

Table 14 – ATC radar systems in Spadeadam vicinity

38. Figure 6 shows the Edinburgh radar predicted coverage for a Hawk aircraft (Typical RCS 2m$^2$) flying at an altitude of 2000ft above the local ground level, the range rings displayed are at 10 nautical mile intervals and the operational range of the Edinburgh radar is 60 nautical miles, it can be seen from Figure 6 that the airspace above each of the proposed wind farms is outside of the Edinburgh radar operational range and therefore Edinburgh is not deemed suitable as an in-fill radar in this case.

39. The blue shaded areas shown in Figure 7 represent the areas in which a wind turbine with a maximum tip height of 100 metres AGL would be visible to the Great Dun Fell radar system (i.e. those areas in which the tip of the turbine blade, when at its vertex, would be within the line-of-sight of the radar). Figure 7 therefore demonstrate that the Great Dun Fell radar has direct line-of-sight the proposed windfarms and that it will therefore suffer in a similar manner to the RAF Spadeadam radar systems.

40. Figure 8 shows the RAF Leeming radar predicted coverage for a Hawk aircraft flying at an altitude of 2000ft AGL, the range rings displayed are at 10 nautical mile intervals and the extent of the RAF Leeming radar coverage is 60 nautical miles. For a controller to utilise the in-fill radar to provide safe passage of aircraft a minimum of 10nm solid radar coverage around the windfarms region is required. It can be seen from Figure 8 that the proposed windfarms are on the edge of the RAF Leeming radar coverage and as such RAF Leeming Watchman radar has insufficient radar coverage to meet the 10nm requirement.

41. Figure 9 shows the Lowther Hill radar predicted coverage for a Hawk aircraft flying at an altitude of 2000ft above the local ground level, the range rings displayed are at 10 nautical mile intervals and the operational Range of the Lowther Hill primary radar is 100 nautical miles. For a controller to utilise the in-fill radar to provide safe passage of aircraft a minimum of 10nm solid radar coverage around the windfarms region is required. It can be seen form Figures 9 to 12 that although the proposed windfarms are well within the Lowther Hill radar operational Range there is insufficient base of radar coverage around the windfarm region until 3500ft AGL, therefore Lowther Hill radar will not meet the needs of RAF Spadeadam (which must at all times be able to detect aircraft flying at a lower altitude).

42. The blue shaded areas shown in Figure 13 represent the areas in which a wind turbine with a maximum tip height of 100 metres AGL would be visible to the Newcastle radar system (i.e. those areas in which the tip of the turbine blade, when at its vertex, would be within the line-of-sight of the radar). Figure 13 therefore demonstrate that the Newcastle radar has direct line-of-sight the proposed windfarms and that it is bound to suffer in a similar manner to the RAF Spadeadam radar systems.

43. Figure 14 shows the Teeside radar predicted coverage for a Hawk Aircraft flying at an altitude of 5000ft above the local ground level, the range rings displayed are at 10 nautical mile intervals and the extent of the Teeside radar coverage at this height is approx 45 nautical miles. For a controller to utilise an in-fill radar to provide safe passage of aircraft a minimum of 10nm solid radar coverage around the windfarms region would be required, Figures 15 and 16 demonstrate this requirement is not meet until 15,000ft AGL and therefore the Teeside radar will not meet the needs of RAF Spadeadam.

44. Based on the above, in my professional assessment, the use of an in-fill radar (or any number of in-fill radars) will not result in any material mitigation of the return signals produced by the turbines: either the detection threshold of the in-fill radars would have to be increased (resulting in wanted return signals not being shown on the radar operators' screens) or if the detection threshold of the infill radars was not increased, a large number of unwanted signals would be displayed on the radar operators' screens; or the in-fill radars would only cover aircraft flying at altitudes well above the military and other aircraft that the radars serving RAF Spadeadam must be able to detect.

45. The third method would be to somehow improve Radar Signal Processing, so as to automatically differentiate the returns from the turbines and those that are wanted and blank the former from the operators' screen. The MoD Watchman radar Engineering and Support Authority, who is responsible for the through-life safety and support of the Watchman radar, anticipates the RAF Spadeadam Watchman radar systems are to remain in service beyond the year 2014. This is based on the current in-service date for the Joint Military Air Traffic Services (JMATS) Project when the Watchman radar is likely to be subjected to either a technical refresh (where obsolescent areas of the radar will be replaced by item which can be support) or the capability provided will replaced in its entirety. A shorter life span will, amongst other things, have a material impact on the defence budget, a significant part of which revolves around equipment being used for its service life.

46. Quite apart from this, despite some advances being made, no radar manufacturer has been able to demonstrate sufficient improvements in radar processing techniques that would allow the MoD to accept that they would allow for the safe control of aircraft in the vicinity of wind turbines. None of the radar manufacturers from whom the MoD purchases radar equipment has offered the MoD radar equipment that the manufacturer asserts would meet the operational requirements of the MoD despite the presence of wind turbines with line-of-sight to the that radar. None of the radar manufacturers from whom the MoD purchase radar equipment has told the MoD that it is developing radar equipment that is both anticipated to be operational and available to the MoD in the next 5 years and will or be likely to meet the operational requirements of the MoD despite the presence of wind turbines with line-of-sight of that radar. In short, I have not seen, read or heard anything reliable to suggest that improved radar signal processing will, is likely to, or even offers a real prospect of providing within the next five years a materially significant mitigation of the adverse effect that are likely to be caused by the proposed wind turbine installations (or any of them).

47. The fourth method would be a reduction in the RCS of wind turbines. With the incorporation of stealth technologies in the turbines, a reduction of RCS is feasible for the radars serving RAF Spadeadam. Significantly, the practicality and the precise measure of its benefits are unproven. For this reason, it is simply not possible to say that the incorporation of stealth technologies will or is likely to provide materially significant mitigation of the adverse effect that are likely to be caused by the proposed wind turbine installations (or any of them). It should be noted that stealth technology reduces the amplitude of (but does not stop) return signals to a radar system.

48.   The fifth method would be Improved Radar Signal Processing combined with a reduction in wind turbines RCS.  An aggregate of technologies, could theoretically be employed to effectively reduce the response from the proposed wind turbines.  If the turbines employed stealth technologies to reduce their RCS ***and*** the radars employed more sophisticated signal processing system this could potentially provide a way forward.  Both these technologies have been discussed at Reference D where MoD and the windfarm community were represented.  However, based upon the current state of technology and knowledge, and for the reasons given for my assessment in relation to each components of the suggested solutions, in my professional assessment such a combination of remedial measures are very unlikely to provide within the next five years a materially significant mitigation of adverse effects that are likely to be caused by the proposed wind turbine installation, or any of them.

**EFFECTS OF THE PROPOSED WIND TURBINE FARMS ON RAF SPADEADAM ATC**

49.   The proposed windfarms at Green Rigg, Ray Estates and Steadings Farm will be clearly visible to both the Berry Hill and Deadwater Fell radar systems and the presence of a number of turbines will have a materially adverse impact on RAF Spadeadam's ability to support Air Traffic Services in each of the following respects:

a. It will result in an increase in displayed clutter. MoD Operational Staff must conduct a detailed study of the effects of the displayed clutter taking into account the required separation distance; in general terms ATC are obliged to pay heed to clutter returns in close proximity to aircraft under their control and would have to assume that such returns were other aircraft in confliction.  Moreover, the presence of a number of clutter returns would mask the returns from real aircraft.

b. It will result in a reduction in radar detection – The Radar's ability to detect aircraft in the vicinity of the wind turbines would be significantly reduced in and around he proposed windfarm locations.

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