PAGERPOWER

Seagreen (Brizlee)

Radar Line of Sight Assessment (Eurocontrol, CAA, RAF, NATS) Brizlee Wood ASACS (RAF)

Pager Power

Seagreen (Brizlee)

7th February 2018

Without Expert Commentary

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Report Issue	Date and Time of Request
1	07 Feb 2018 at 09:13 BST

This assessment was requested by Mike Watson of Pager Power on 7th February 2018.

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1 SUMMARY (EXECUTIVE)

Pager Power
Pager Power was registered in England in 1997 and is made up of a team of specialist professionals, based near Cambridge. We are a truly international business with more than 250 clients from across the globe. Our reputation has been established as experts able to assess and provide solutions to issues that can arise with any combination of wind turbines, radar, radio communications and construction interaction. We strongly believe that our greatest assets are our people and our software.

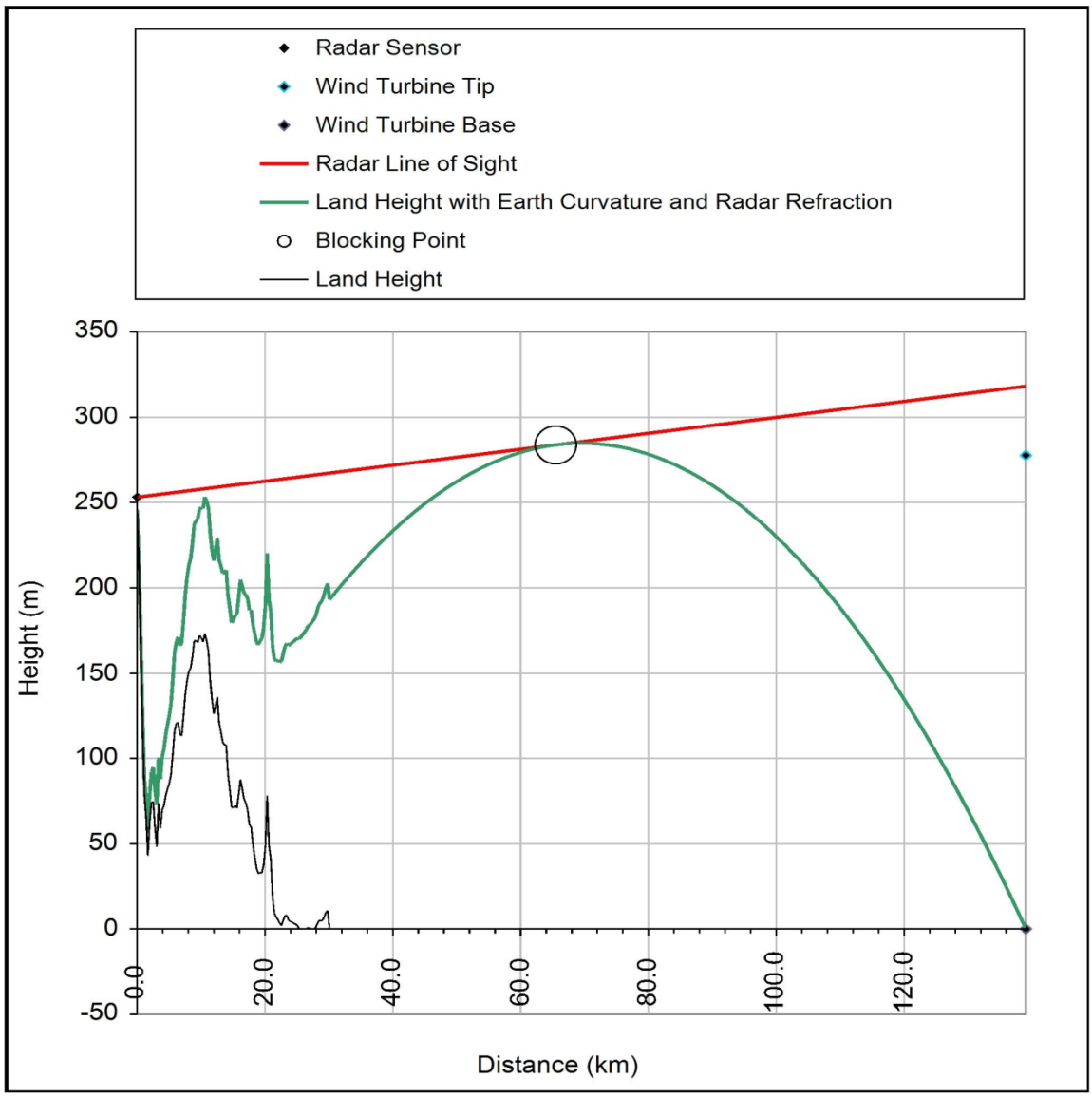
Purpose
The purpose of this assessment is to enable swift and cost effective decision making by wind turbine developers and radar operators. The optional Expert Commentary offers advice as to the next steps that should be taken as a result of the findings of this report. Radar Line of Sight Calculations are used extensively in the planning stages of wind farm development and are referenced by many leading authorities and organisations, including civil and military radar operators.

Wind Turbine	Result
A1	**HIDDEN**
A2	**HIDDEN**
A3	**HIDDEN**
A4	**VISIBLE**
A5	**VISIBLE**
A6	**VISIBLE**
A7	**VISIBLE**
A8	**VISIBLE**

B1	**VISIBLE**
B2	**VISIBLE**
B3	**VISIBLE**
B4	**VISIBLE**
B5	**VISIBLE**
B6	**VISIBLE**
Explanation: There is one Radar Line of Sight Calculation page for each turbine assessed. Each calculation shows whether the turbine is **VISIBLE** or **HIDDEN**. Visible turbines are likely to affect the radar whereas hidden turbines are unlikely to affect the radar.	

Radar Line of Sight Calculation
Prepared for Pager Power Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	A1
Result	HIDDEN
Certainty	40.5 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E405537 N752516**
Distance to radar (km)	**139.1**
Blocking Point Location	**E410438 N679142**
Distance to BP (km)	**73.5**

Additional Analysis	
Angle (Radar to Tip)	**0.459 degrees down**
Maximum Tip Height	**318.25 metres**

See Appendix for further information

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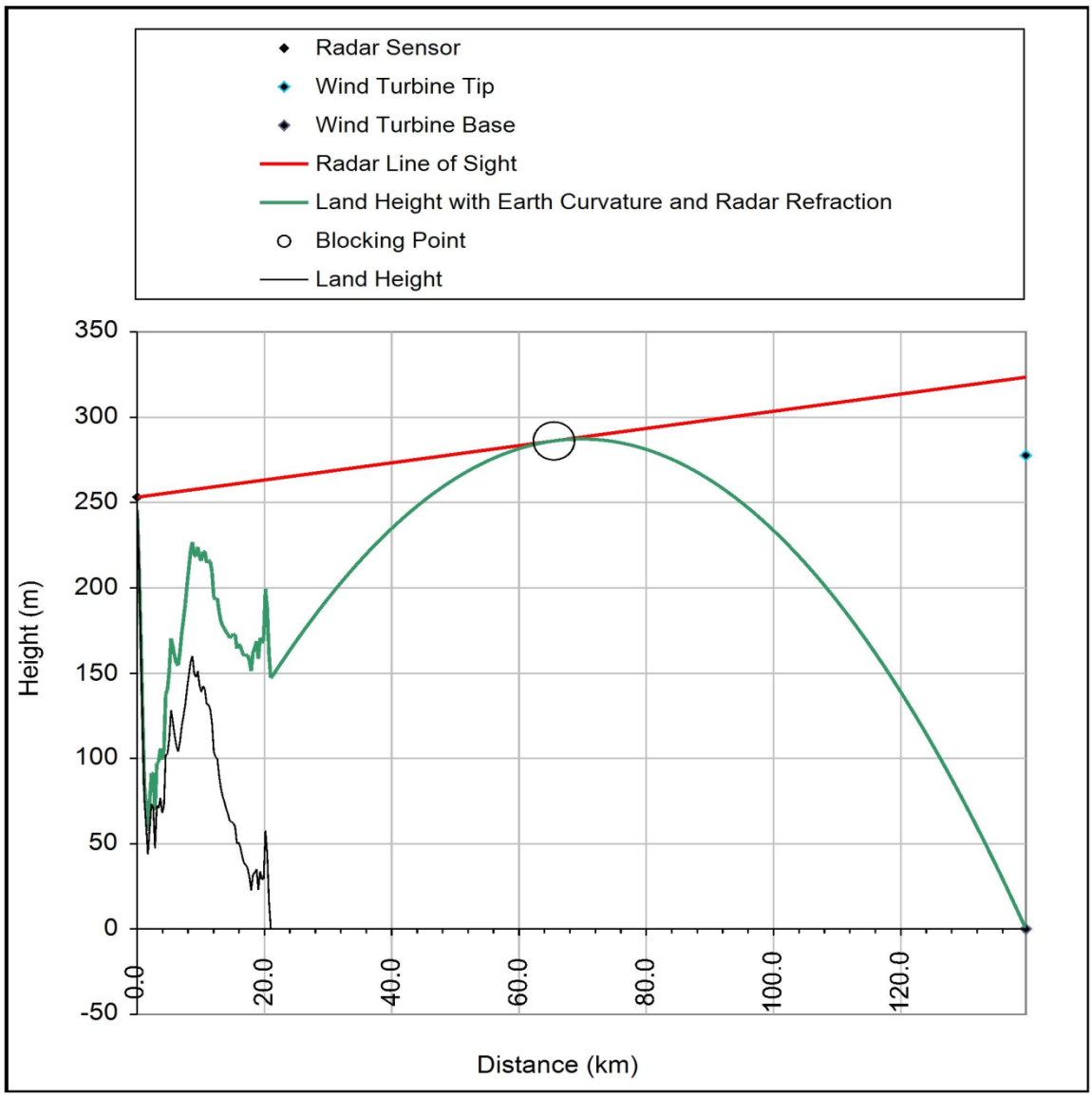
Radar Line of Sight Calculation	
Prepared for Pager Power Brizlee Wood ASACS (RAF)	

Seagreen (Brizlee)	
Turbine	A2
Result	HIDDEN
Certainty	45.8 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E416645 N753421**
Distance to radar (km)	**139.7**
Blocking Point Location	**E415666 N679288**
Distance to BP (km)	**74.1**

Additional Analysis	
Angle (Radar to Tip)	**0.461 degrees down**
Maximum Tip Height	**323.53 metres**

See Appendix for further information

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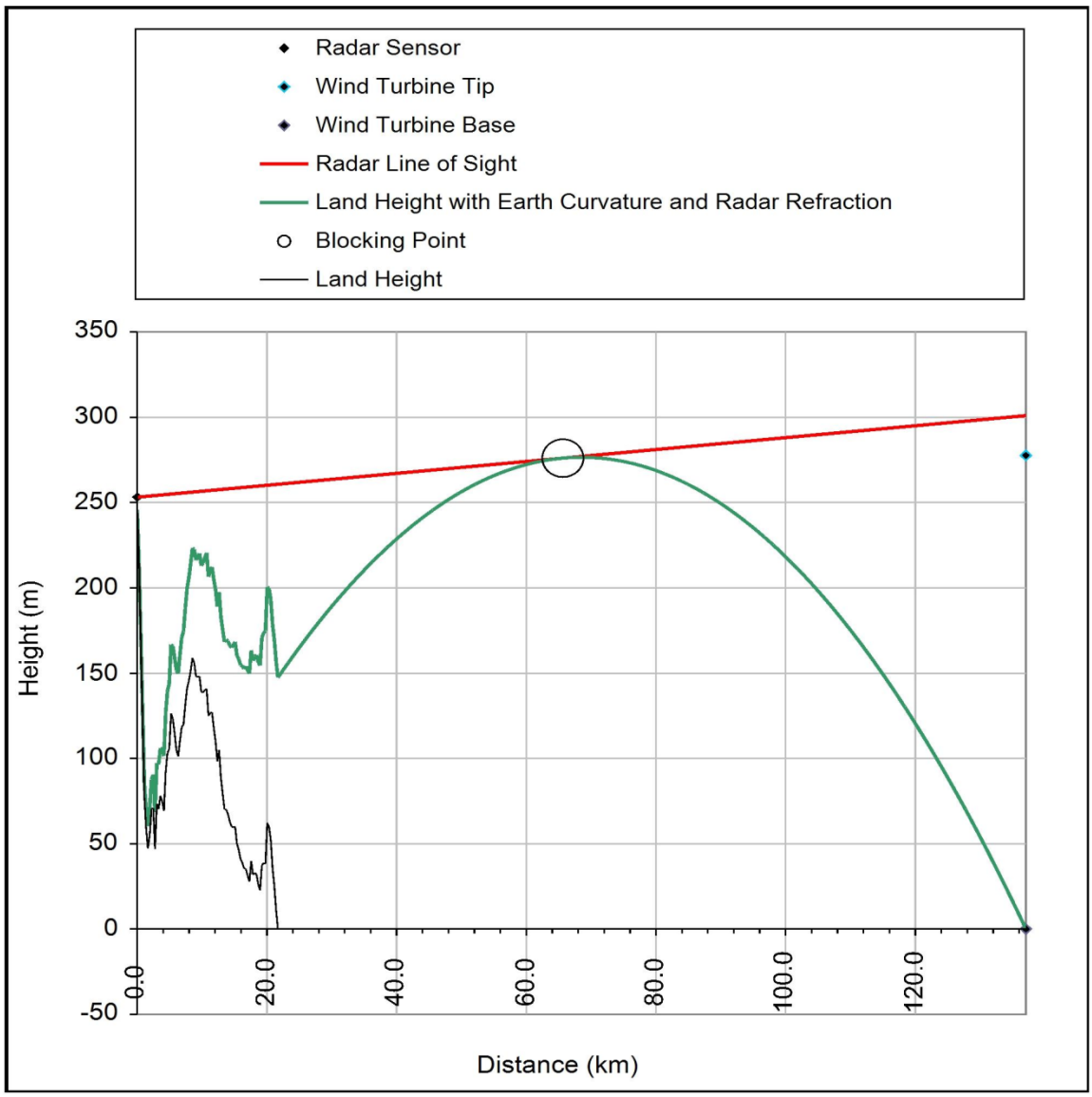
Radar Line of Sight Calculation	
Prepared for Pager Power Brizlee Wood ASACS (RAF)	

Seagreen (Brizlee)	
Turbine	A3
Result	HIDDEN
Certainty	23.3 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E418820 N750751**
Distance to radar (km)	**137.0**
Blocking Point Location	**E416726 N679408**
Distance to BP (km)	**71.4**

Additional Analysis	
Angle (Radar to Tip)	**0.452 degrees down**
Maximum Tip Height	**301.02 metres**

See Appendix for further information

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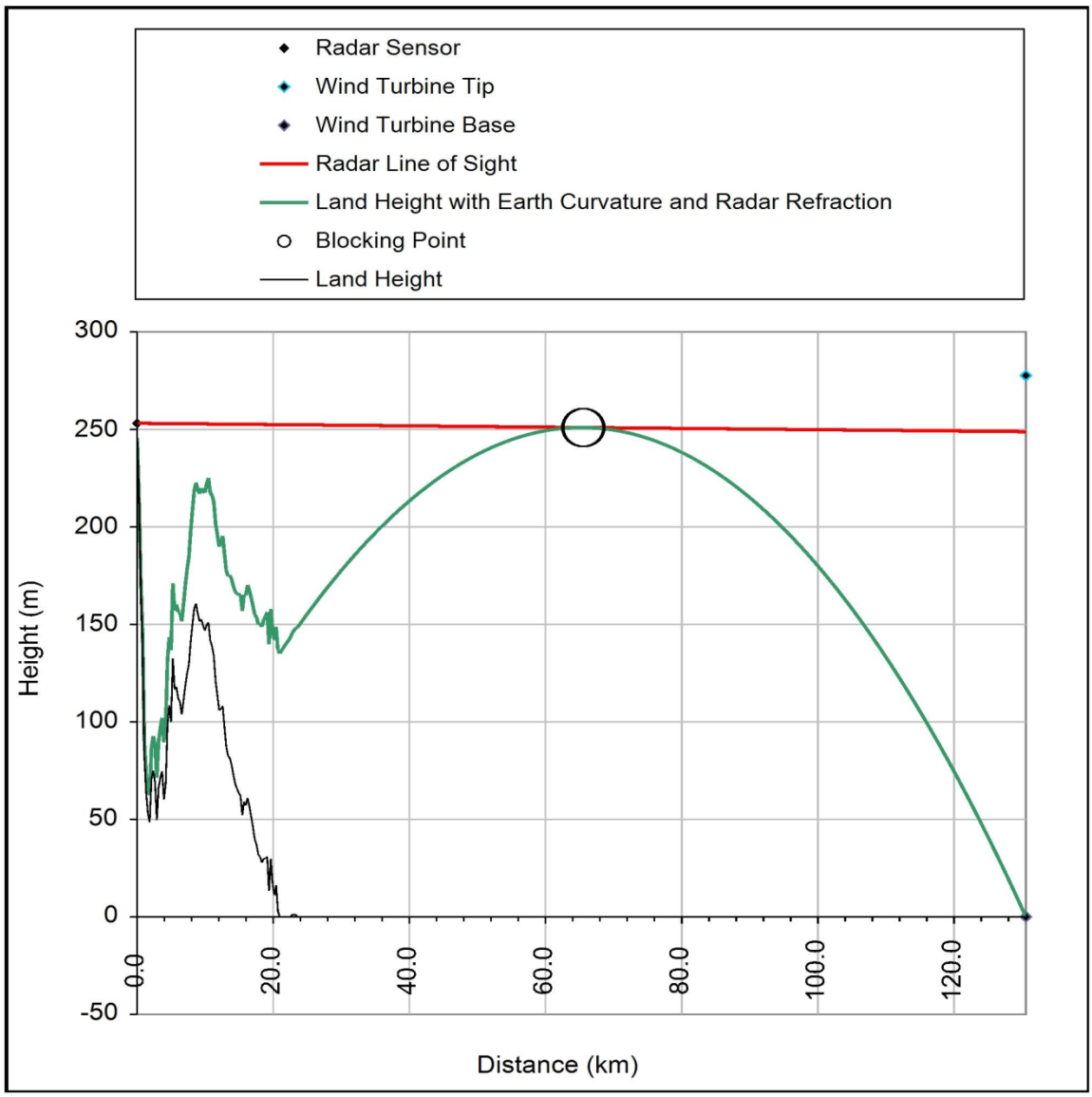
Radar Line of Sight Calculation
Prepared for Pager Power Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	A4
Result	VISIBLE
Certainty	28.8 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E414574 N744331**
Distance to radar (km)	**130.6**
Blocking Point Location	**E414687 N679472**
Distance to BP (km)	**64.9**

Additional Analysis	
Angle (Radar to Tip)	**0.430 degrees down**
Maximum Tip Height	**248.91 metres**

See Appendix for further information

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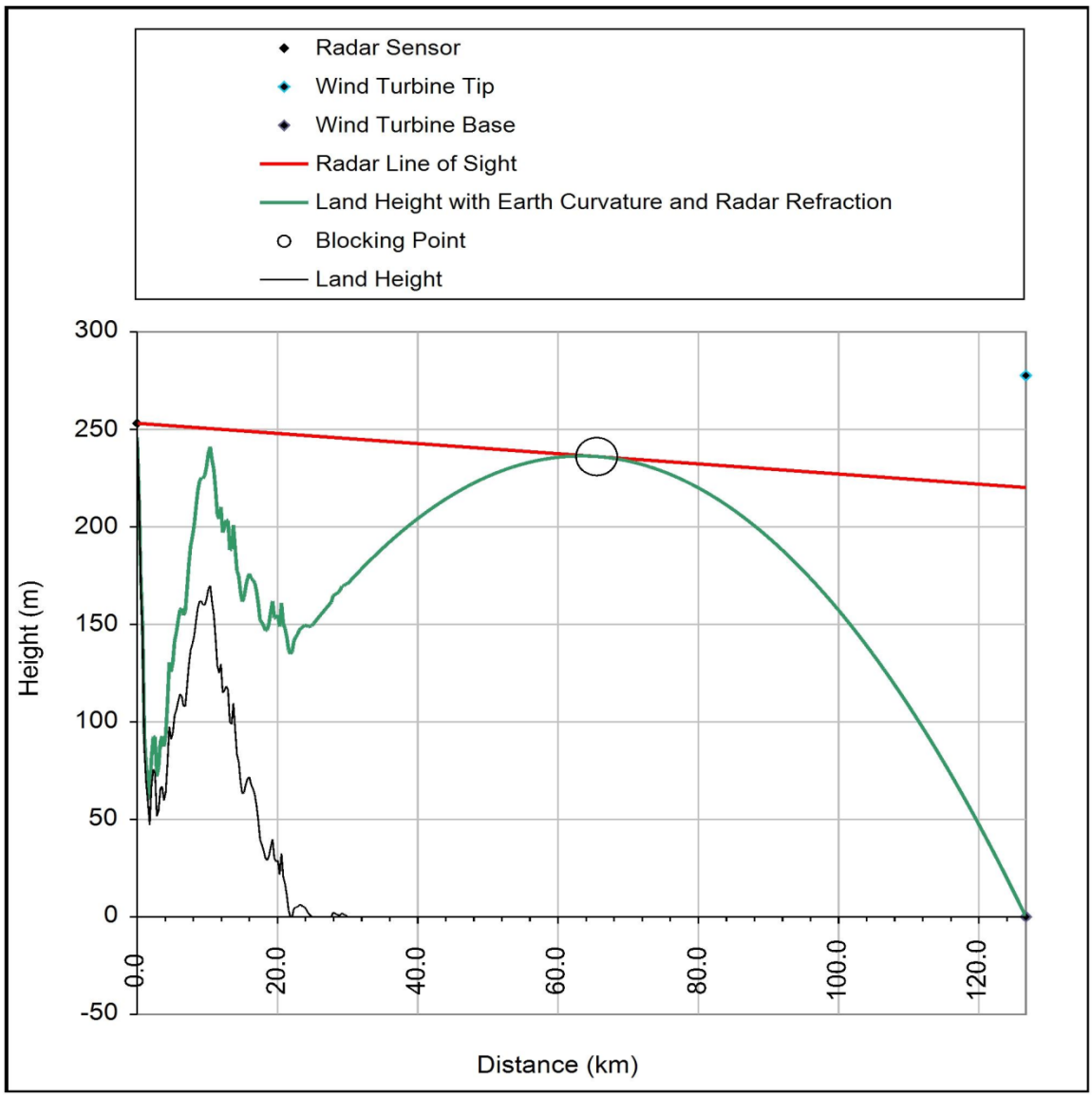
Radar Line of Sight Calculation
Prepared for Pager Power Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	A5
Result	VISIBLE
Certainty	57.5 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E410664 N740406**
Distance to radar (km)	**126.7**
Blocking Point Location	**E412662 N679273**
Distance to BP (km)	**61.2**

Additional Analysis	
Angle (Radar to Tip)	**0.416 degrees down**
Maximum Tip Height	**220.23 metres**

See Appendix for further information

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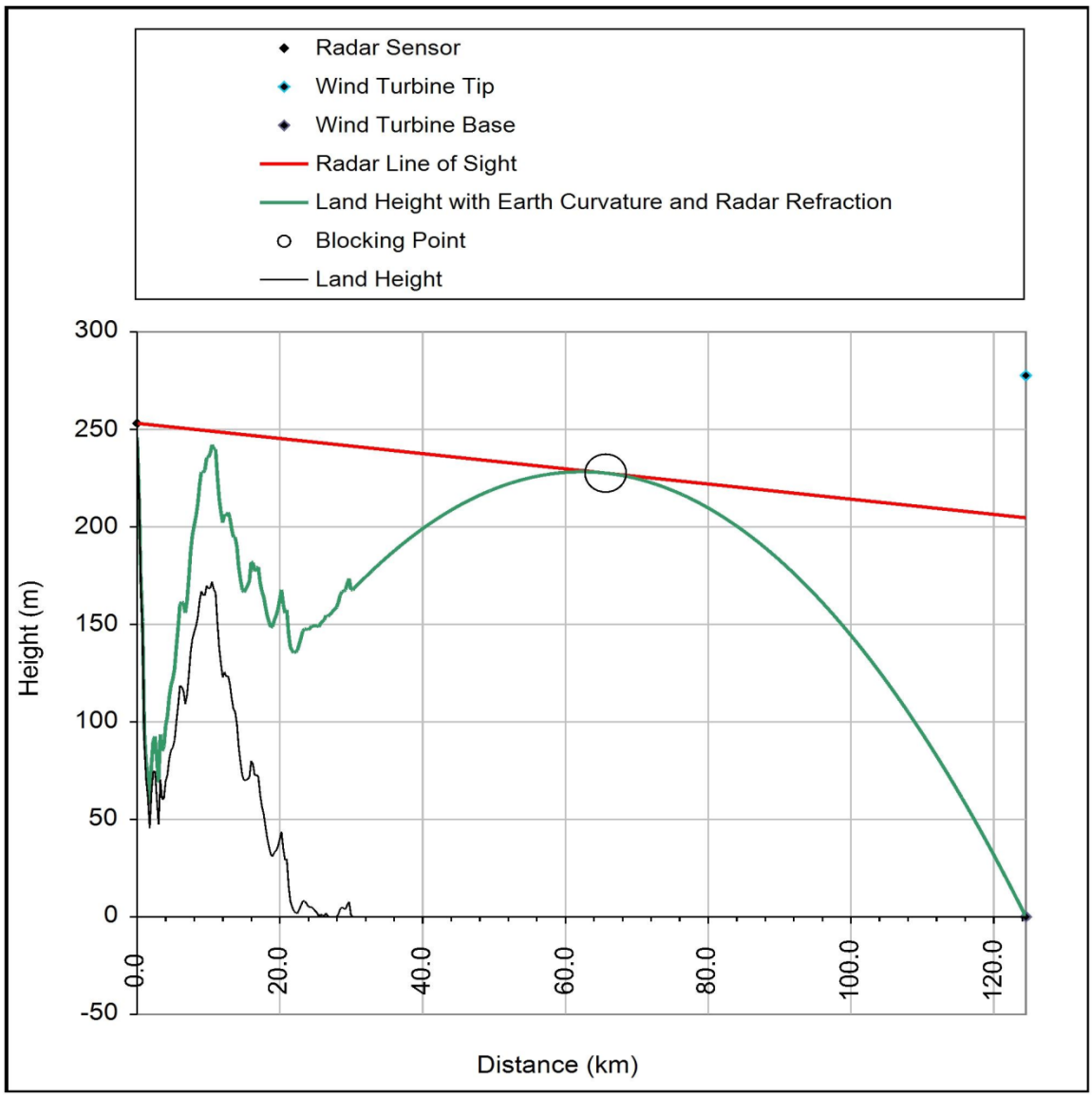
Radar Line of Sight Calculation
Prepared for Pager Power Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	A6
Result	VISIBLE
Certainty	73.0 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E407815 N738086**
Distance to radar (km)	**124.5**
Blocking Point Location	**E411119 N679319**
Distance to BP (km)	**58.9**

Additional Analysis	
Angle (Radar to Tip)	**0.409 degrees down**
Maximum Tip Height	**204.72 metres**

See Appendix for further information

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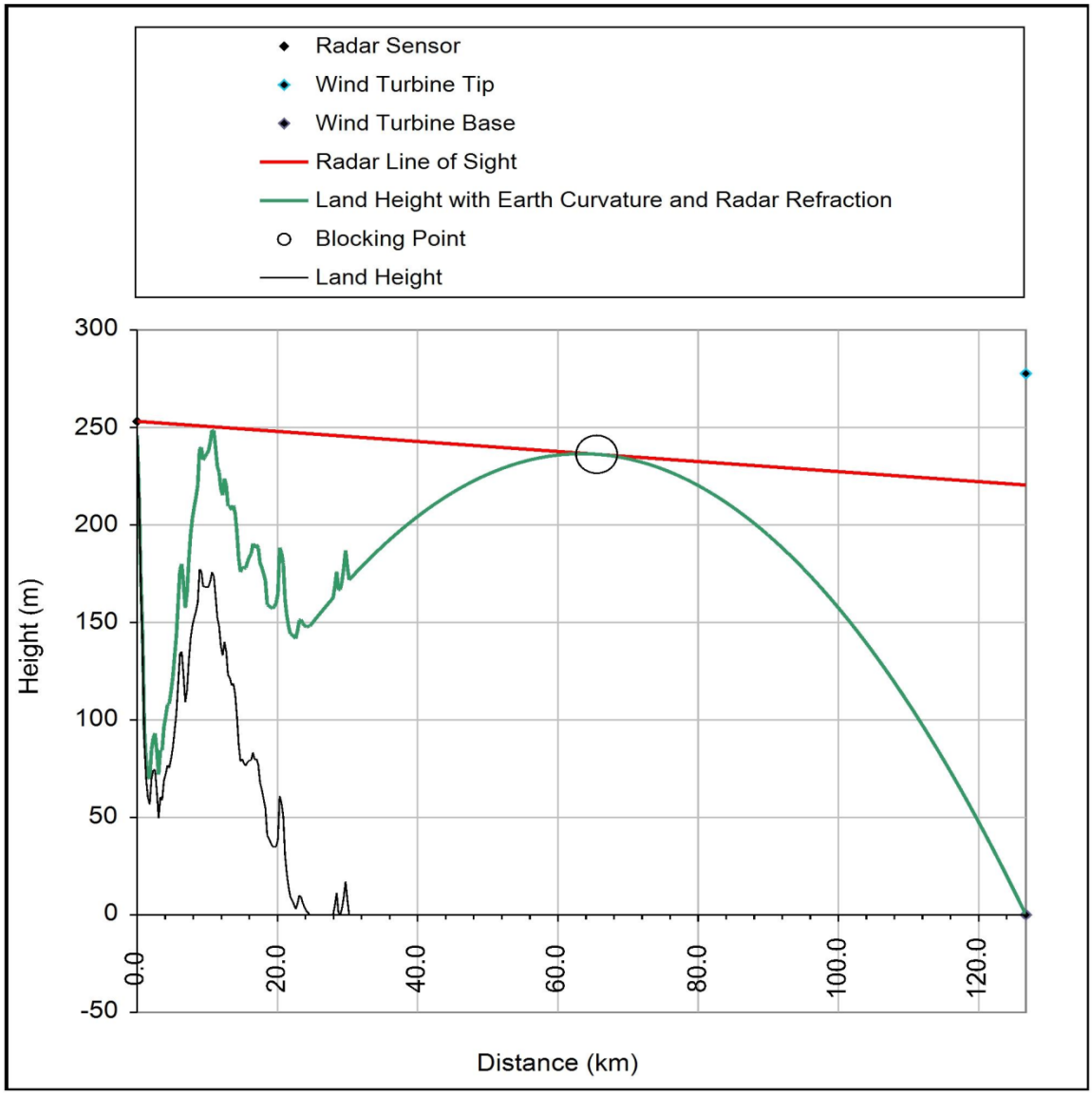
Radar Line of Sight Calculation
Prepared for Pager Power Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	A7
Result	VISIBLE
Certainty	57.2 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E403854 N740041**
Distance to radar (km)	**126.7**
Blocking Point Location	**E409141 N679084**
Distance to BP (km)	**61.2**

Additional Analysis	
Angle (Radar to Tip)	**0.416 degrees down**
Maximum Tip Height	**220.53 metres**

See Appendix for further information

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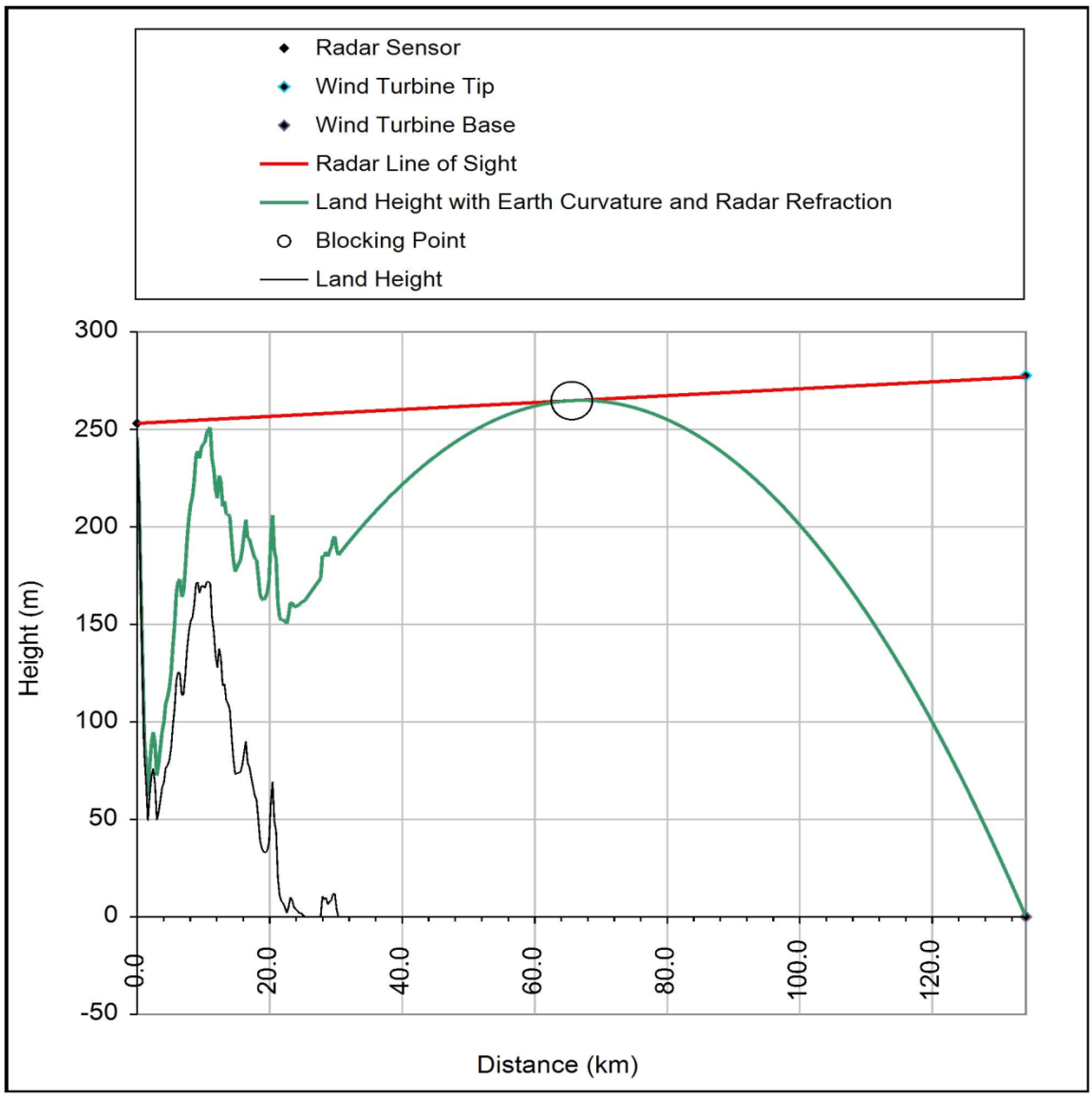
Radar Line of Sight Calculation
Prepared for Pager Power Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	A8
Result	VISIBLE
Certainty	0.7 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E404864 N747526**
Distance to radar (km)	**134.1**
Blocking Point Location	**E409942 N679203**
Distance to BP (km)	**68.5**

Additional Analysis	
Angle (Radar to Tip)	**0.442 degrees down**
Maximum Tip Height	**276.97 metres**

See Appendix for further information

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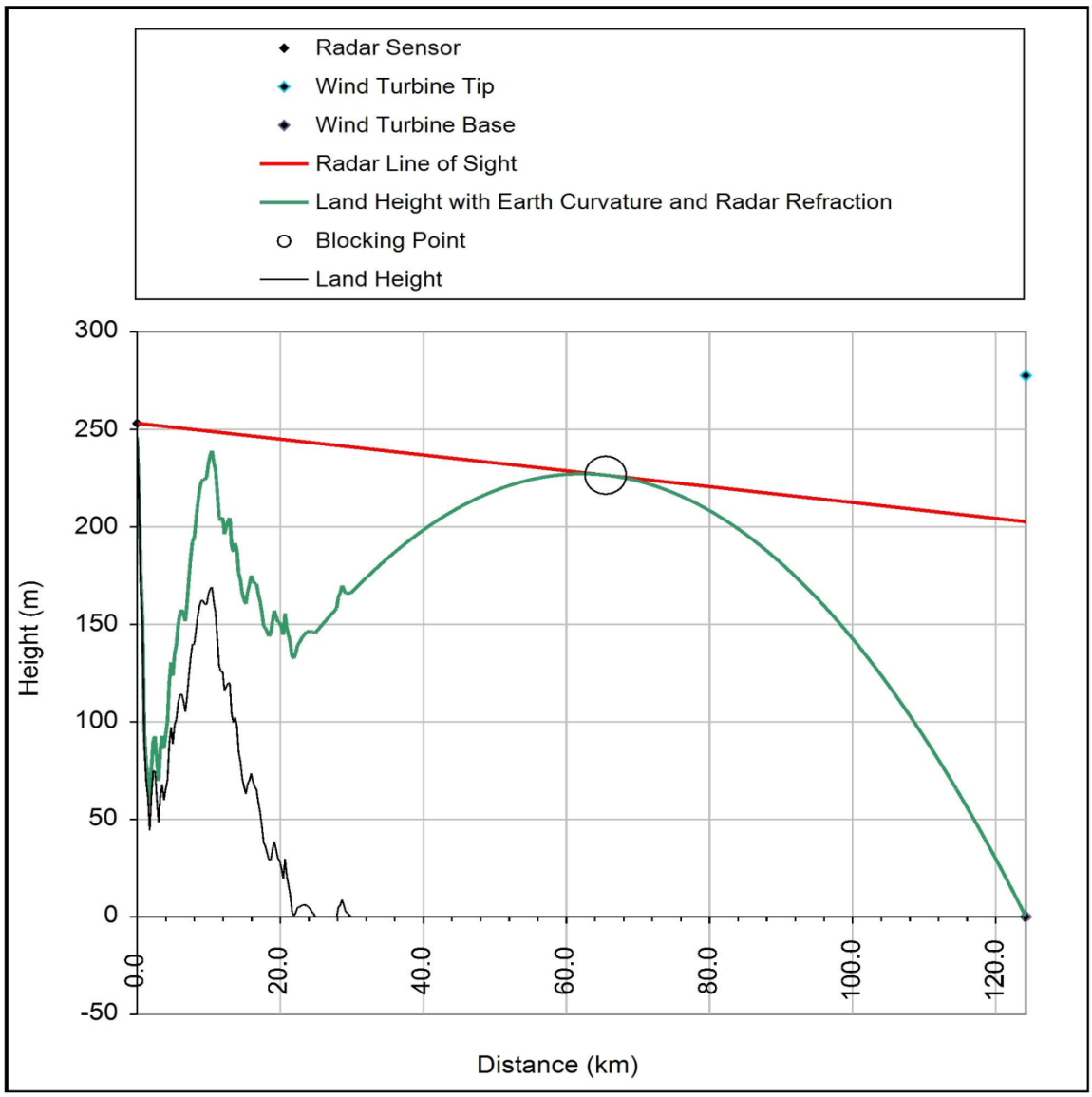
Radar Line of Sight Calculation
Prepared for Pager Power Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	B1
Result	VISIBLE
Certainty	75.0 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E410328 N737911**
Distance to radar (km)	**124.2**
Blocking Point Location	**E412443 N679226**
Distance to BP (km)	**58.7**

Additional Analysis	
Angle (Radar to Tip)	**0.408 degrees down**
Maximum Tip Height	**202.71 metres**

See Appendix for further information

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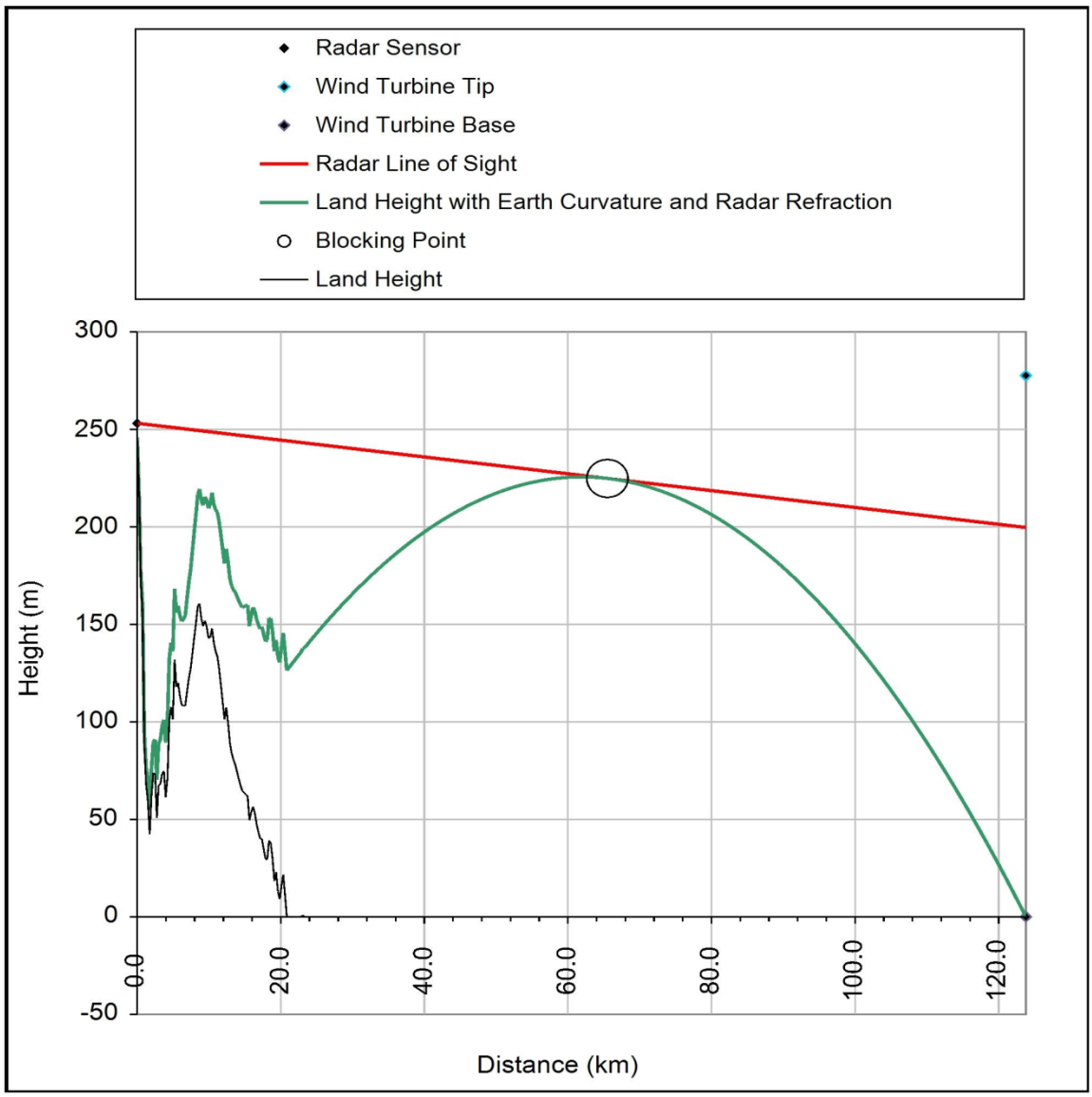
Radar Line of Sight Calculation
Prepared for Pager Power Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	B2
Result	VISIBLE
Certainty	78.0 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E415351 N737561**
Distance to radar (km)	**123.8**
Blocking Point Location	**E415092 N679290**
Distance to BP (km)	**58.3**

Additional Analysis	
Angle (Radar to Tip)	**0.406 degrees down**
Maximum Tip Height	**199.75 metres**

See Appendix for further information

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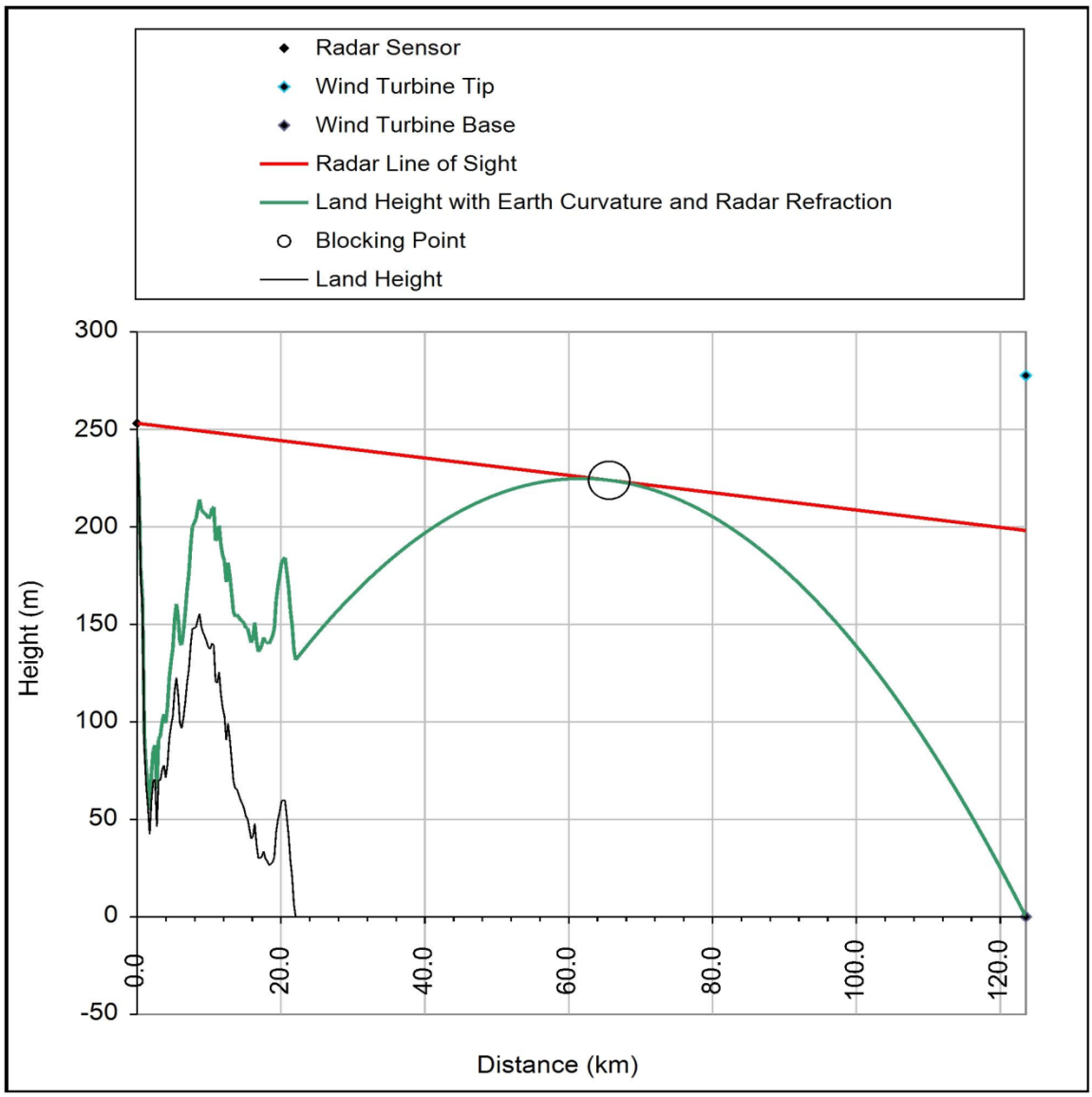
Radar Line of Sight Calculation
Prepared for Pager Power
Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	B3
Result	VISIBLE
Certainty	79.5 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E420374 N737211
Distance to radar (km)	123.6
Blocking Point Location	E417761 N679352
Distance to BP (km)	57.9

Additional Analysis	
Angle (Radar to Tip)	0.405 degrees down
Maximum Tip Height	198.20 metres

See Appendix for further information

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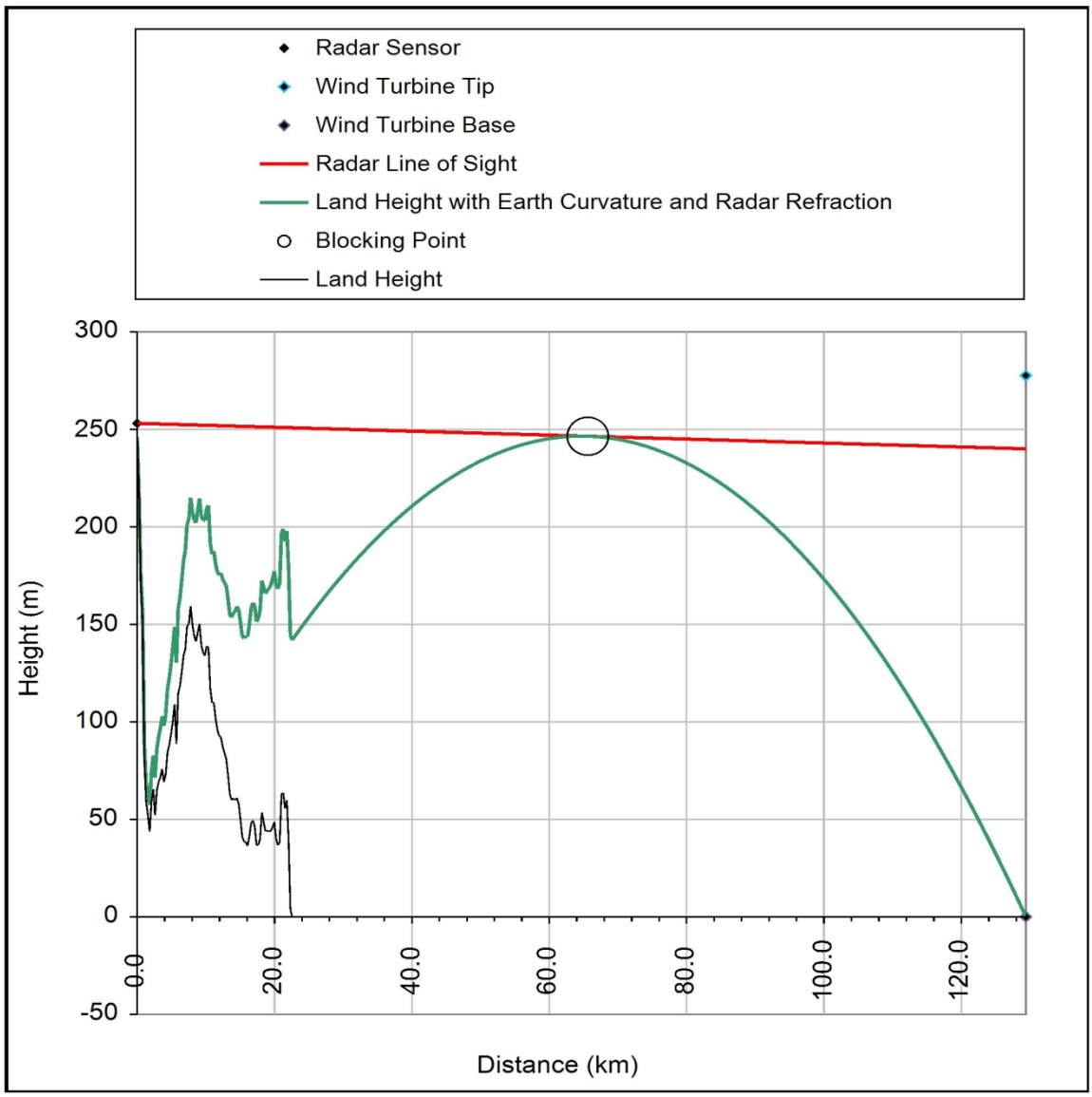
Radar Line of Sight Calculation
Prepared for Pager Power Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	B4
Result	VISIBLE
Certainty	37.6 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E425345 N742741**
Distance to radar (km)	**129.4**
Blocking Point Location	**E420147 N679188**
Distance to BP (km)	**63.8**

Additional Analysis	
Angle (Radar to Tip)	**0.426 degrees down**
Maximum Tip Height	**240.10 metres**

See Appendix for further information

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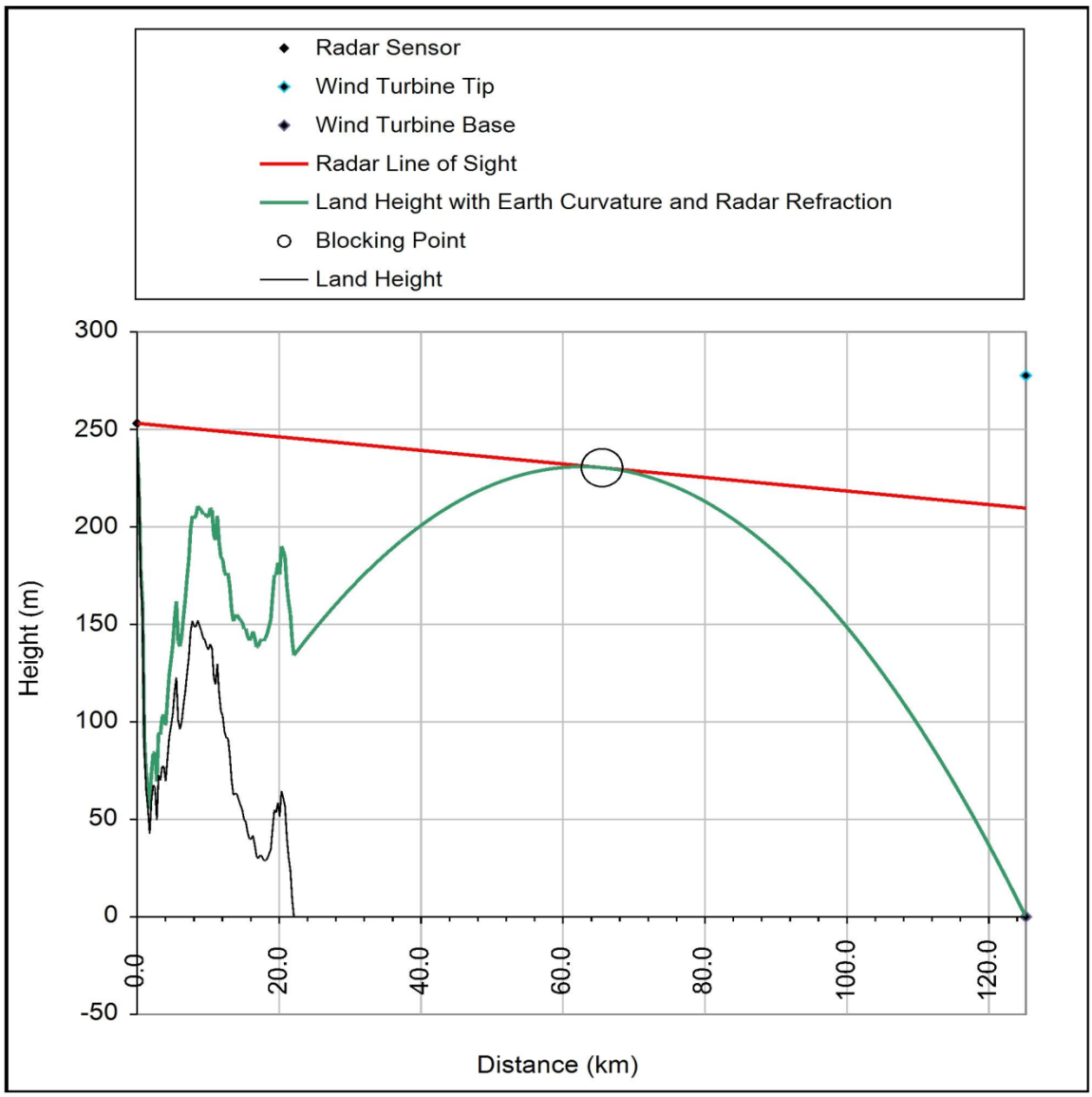
Radar Line of Sight Calculation
Prepared for Pager Power Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	B5
Result	VISIBLE
Certainty	68.0 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E421435 N738816**
Distance to radar (km)	**125.2**
Blocking Point Location	**E418271 N679202**
Distance to BP (km)	**59.7**

Additional Analysis	
Angle (Radar to Tip)	**0.411 degrees down**
Maximum Tip Height	**209.68 metres**

See Appendix for further information

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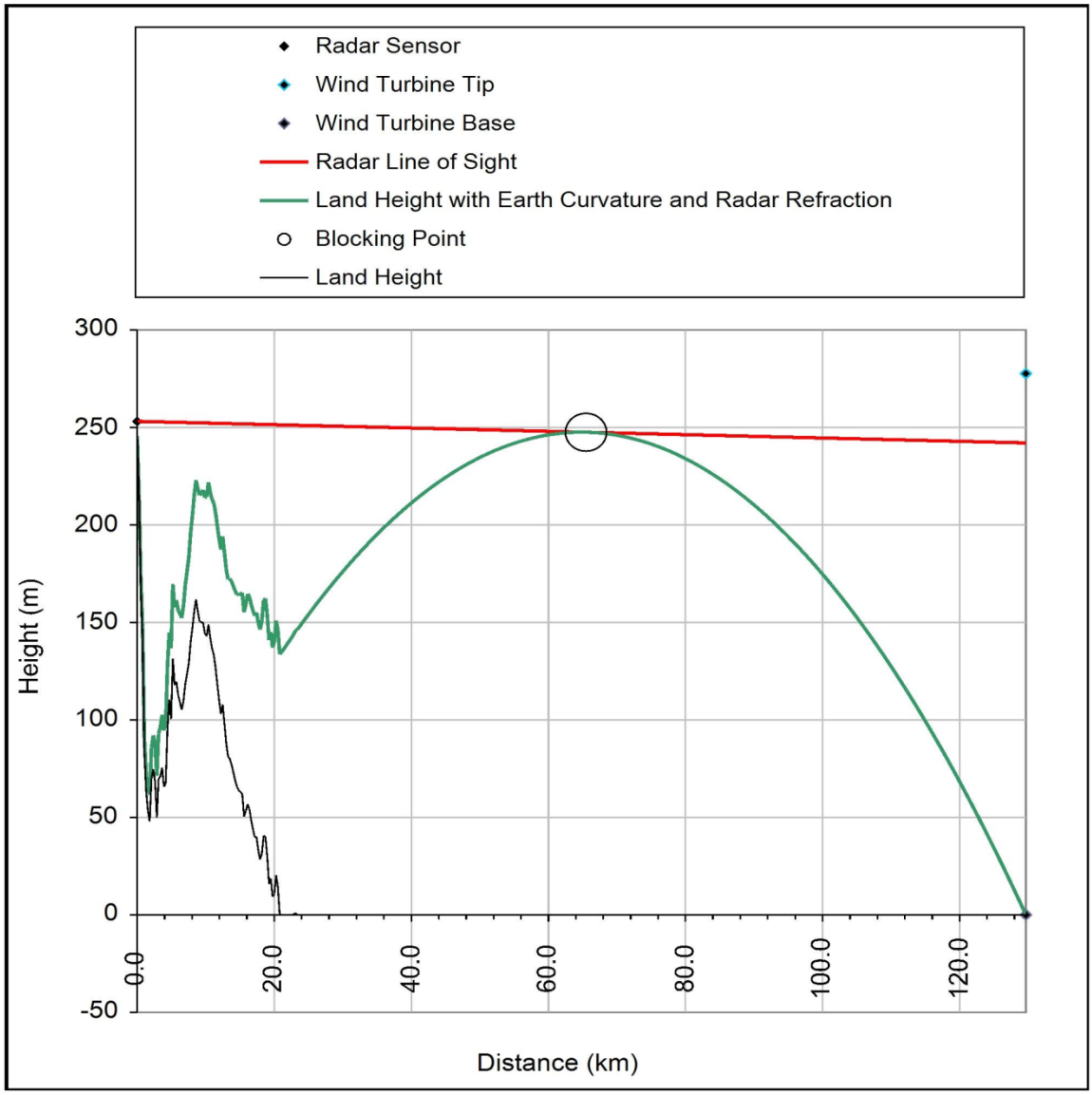
Radar Line of Sight Calculation
Prepared for Pager Power Brizlee Wood ASACS (RAF)

Seagreen (Brizlee)	
Turbine	B6
Result	VISIBLE
Certainty	35.6 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E415299 N743441**
Distance to radar (km)	**129.7**
Blocking Point Location	**E415052 N679284**
Distance to BP (km)	**64.2**

Additional Analysis	
Angle (Radar to Tip)	**0.426 degrees down**
Maximum Tip Height	**242.14 metres**

See Appendix for further information

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2 RESULTS SUMMARY

Wind Turbine	Result	Certainty	Angle (Radar to Tip)	Maximum Height
A1	HIDDEN	40.5 metres	0.459 degrees down	318.25 metres
A2	HIDDEN	45.8 metres	0.461 degrees down	323.53 metres
A3	HIDDEN	23.3 metres	0.452 degrees down	301.02 metres
A4	VISIBLE	28.8 metres	0.430 degrees down	248.91 metres
A5	VISIBLE	57.5 metres	0.416 degrees down	220.23 metres
A6	VISIBLE	73.0 metres	0.409 degrees down	204.72 metres
A7	VISIBLE	57.2 metres	0.416 degrees down	220.53 metres
A8	VISIBLE	0.7 metres	0.442 degrees down	276.97 metres
B1	VISIBLE	75.0 metres	0.408 degrees down	202.71 metres
B2	VISIBLE	78.0 metres	0.406 degrees down	199.75 metres
B3	VISIBLE	79.5 metres	0.405 degrees down	198.20 metres
B4	VISIBLE	37.6 metres	0.426 degrees down	240.10 metres
B5	VISIBLE	68.0 metres	0.411 degrees down	209.68 metres
B6	VISIBLE	35.6 metres	0.426 degrees down	242.14 metres

Column Descriptions	
Wind Turbine	Turbine Number as entered or uploaded
Result	VISIBLE turbines are likely to affect the radar whereas HIDDEN turbines are unlikely to affect the radar.

Certainty	This is a vertical distance in metres and is the distance from the turbine tip to the line of sight. The higher the number the greater the certainty.
Angle (Radar to Tip)	This is the vertical angle from the radar to the wind turbine tip. Some radar are less likely to be affected by a wind turbine if this angle is down and more likely to be affected if this angle is up.
Maximum Height	A turbine having this tip height would be **HIDDEN**. A turbine that was any higher would be **VISIBLE**.

3 REQUESTED ASSESSMENT

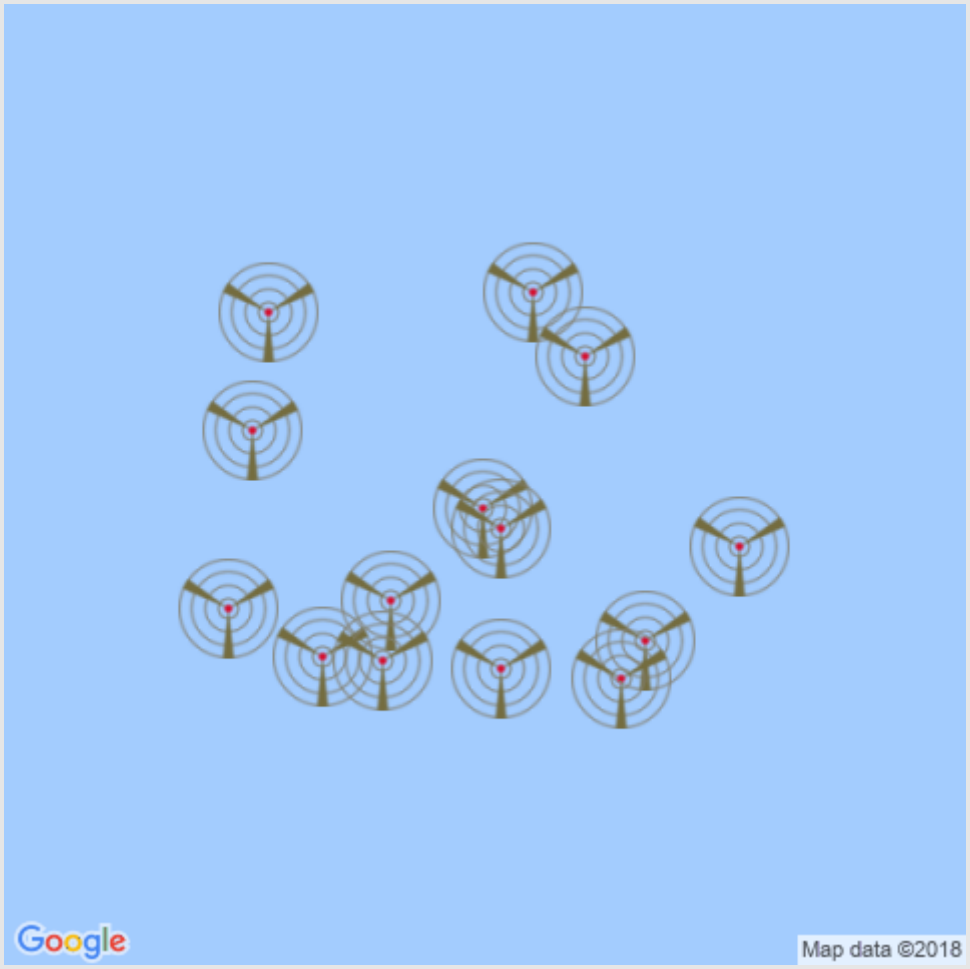
Key Parameters
• This Radar Line of Sight Assessment for Seagreen (Brizlee) was requested by Mike Watson of Pager Power on 7th February 2018. • Assessment Methodology = Radar Line of Sight Calculation using advanced terrain data processing algorithm. • Coordinate System = Local Grid • Vertical Units = Metres

Radar
• The assessed radar was Brizlee Wood ASACS (RAF) • Location and height information for preselected radar are sourced from a managed database

Development Location Data (as entered in online system)				
Coordinate (E)	**Coordinate (N)**	**Hub Height (Metres AGL)**	**Tip Height (Metres AGL)**	**Wind Turbine Reference**
405537.29	752516.24	220	277.7	A1
416644.98	753420.86	220	277.7	A2
418819.9	750750.77	220	277.7	A3
414573.7	744330.85	220	277.7	A4
410664.08	740405.88	220	277.7	A5
407815	738085.89	220	277.7	A6
403854.44	740040.99	220	277.7	A7
404864.12	747526.15	220	277.7	A8
410327.54	737910.85	220	277.7	B1
415350.59	737560.78	220	277.7	B2

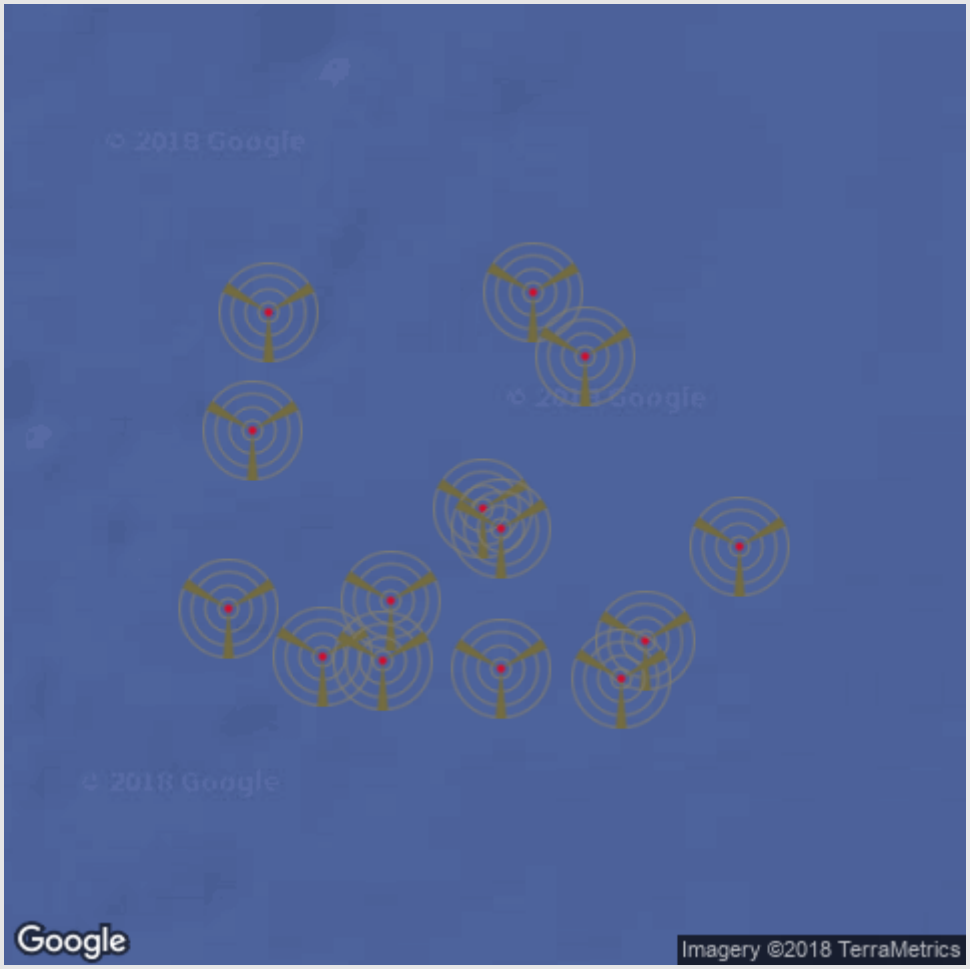
420373.6	737210.72	220	277.7	B3
425344.67	742740.62	220	277.7	B4
421435.12	738815.7	220	277.7	B5
415298.69	743440.83	220	277.7	B6

Map Showing Assessed Turbine Locations



Seagreen (Brizlee)

Aerial Photograph Showing Assessed Turbine Locations



Seagreen (Brizlee)

4 METHODOLOGY AND BACKGROUND

Introduction

This report indicates whether wind turbines at the Seagreen (Brizlee) will be detected by the Brizlee Wood ASACS (RAF). This assessment shows:

- Whether wind turbines are **VISIBLE** or **HIDDEN**
- A level of certainty as to whether each wind turbine is likely to affect the radar or not
- A profile chart showing the radar, each wind turbine and intervening terrain

Scope

This assessment:

- Is new and takes no previous assessment into account
- Determines whether each assessed wind turbine at Seagreen (Brizlee) will be within Radar Line of Sight of the Brizlee Wood ASACS (RAF)
- Does not account for diffraction effects or any other radar
- Does account for terrain, earth curvature and refraction effects
- Uses an advanced terrain data processing algorithm optimized for accurate and reliable wind farm radar calculations

Official Guidance Details

The following organisations have published documents that refer to the use of Radar Line of Sight Calculations for determining whether a wind turbine will affect a radar.

1. European Organisation for the Safety of Air Navigation (EUROCONTROL)
2. UK Civil Aviation Authority (CAA)
3. UK Royal Air Force (RAF)
4. UK Wind Energy, Defence and Civil Aviation Interests Working Group
5. UK National Air Traffic Services (NATS)
6. US Department of Defense (DoD)
7. US Department of Commerce
8. US Federal Aviation Authority (FAA)
9. South African Weather Service (SAWS)
10. Radio Advisory Board of Canada (RABC)
11. Canadian Wind Energy Association (CanWEA)

Report Preparation

This report has been created by a custom-built advanced online service which has the following features:

- Fast report delivery by email
- Responsive and knowledgeable technical support team
- Advanced terrain data processing algorithms

Radar Line of Sight Calculation – Accuracy Details

- Terrain data used normally has a vertical accuracy of better than 3 metres.
- Comparisons and site measurements suggest the terrain data used has a vertical accuracy of around 2 metres.
- This gives a typical accuracy of 4 metres for Radar Line of Sight Calculation results.
- Process accuracy is enhanced and designed to give cautious results by:

A. Using software developed specifically for wind turbine radar calculations

B. Using a weighted average algorithm to determine terrain elevation from terrain data

C. Using an algorithm that underestimates, rather than overestimates, terrain peaks

D. Using terrain rather than surface data (Great Britain only)

E. Using terrain data that sometimes under-represents peaks (Great Britain only)

F. Continuous software development and improvement specifically for Radar Line of Sight Calculations

G. Continuous process for managing radar position and height data

5 APPENDIX - CALCULATION NOTES

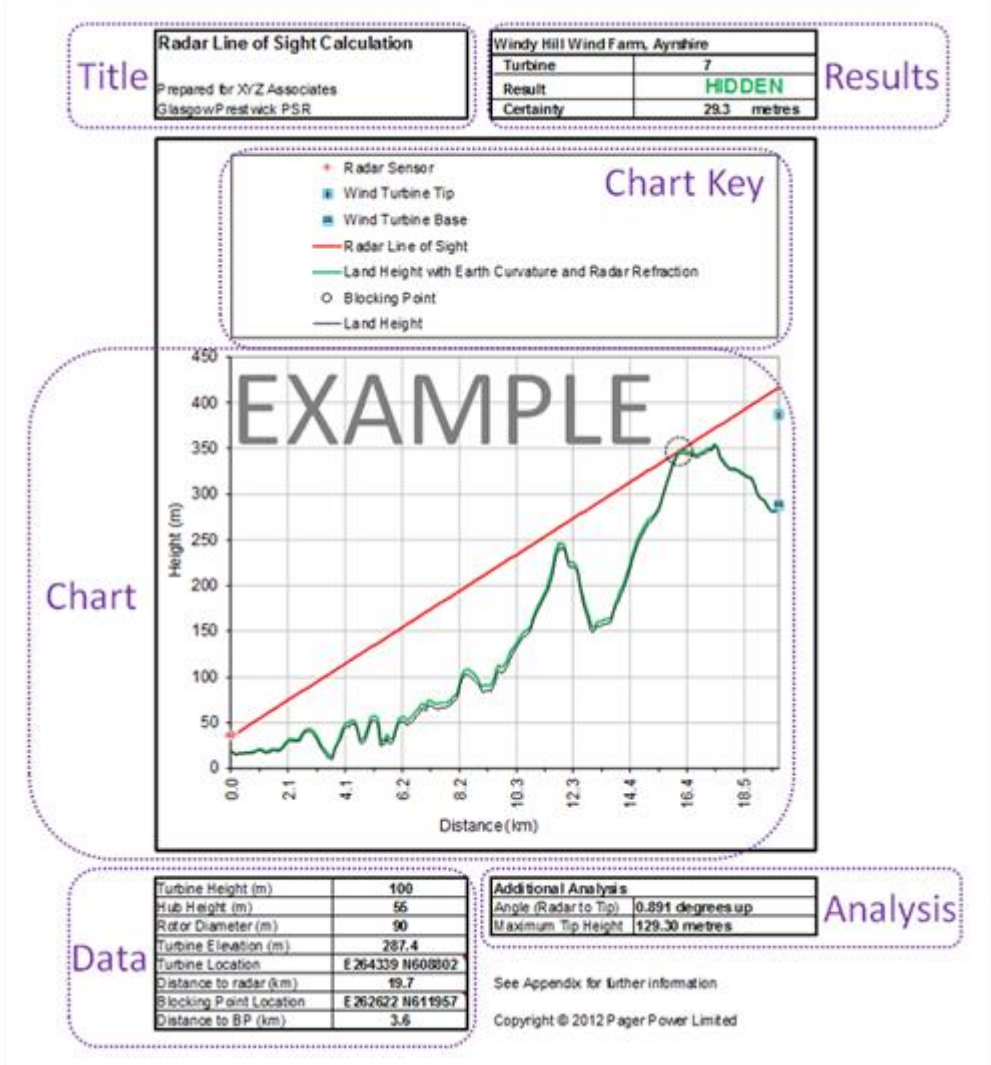


Diagram showing areas of a Radar Line of Sight Calculation

The information in the various areas of the calculation sheet is described below:

Title Details
Name of organisation that has requested the calculation (As given when setting up Pager Power Online user account)
Name of the radar (As selected or entered)

Results	
Name of the development (As entered)	
Turbine	Turbine Number as entered or uploaded
Result	**VISIBLE** turbines are likely to affect the radar whereas **HIDDEN** turbines are unlikely to affect the radar.
Certainty	This is a vertical distance in metres and is the distance from the turbine tip to the line of sight. The higher the number the greater the certainty.

Chart Key	
Radar Sensor	This is the radar antenna. It is a single point at the left of the chart.
Wind Turbine Tip	This is the highest point of the wind turbine. It is a single point at the right of the chart.
Wind Turbine Base	This is the bottom of the turbine. It is a single point at the right of the chart.
Radar Line of Sight	This is a straight line from the Radar Sensor towards the turbine which coincides with the terrain between the radar and the wind turbine.
Land Height with Earth Curvature and Radar Refraction	This is the terrain profile between the radar and the turbine. Calculation accuracy is increased by including both Earth curvature and standard radar refraction. Refraction means that the radar signal bends slightly as it passes through the atmosphere.
Blocking Point	This is a single point where the Radar Line of Sight is the same as Land Height with Earth Curvature and Refraction.
Land Height	This is calculated accurately using an advanced weighted average algorithm and height data from a terrain database.

Chart	
Vertical Axis	Height above sea level in metres
Horizontal Axis	Distance from the radar in kilometres

Data	
Turbine Height (m)	The maximum turbine tip height above ground level in metres.
Hub Height (m)	The turbine hub height above ground level in metres.
Rotor Diameter (m)	The diameter of the area swept by the turbine blades in metres. The Rotor Radius is half of the Rotor Diameter.
Turbine Elevation (m)	The height of the ground on which the turbine stands relative to sea level.
Turbine Location	The coordinates of the turbine location.
Distance to radar (km)	The horizontal distance from the radar to the turbine in kilometres.
Blocking Point Location	The coordinates of the Blocking Point. Buildings and trees at this location might mean the radar is less likely to be affected by the wind turbine.
Distance to BP (km)	The horizontal distance from the turbine to the Blocking Point in kilometres.

Analysis	
Angle (Radar to Tip)	This is the vertical angle from the radar to the wind turbine tip. Some radar are less likely to be affected by a wind turbine if this angle is down.
Maximum Height	A turbine having this tip height would be **HIDDEN**. A turbine that was any higher would be **VISIBLE**.