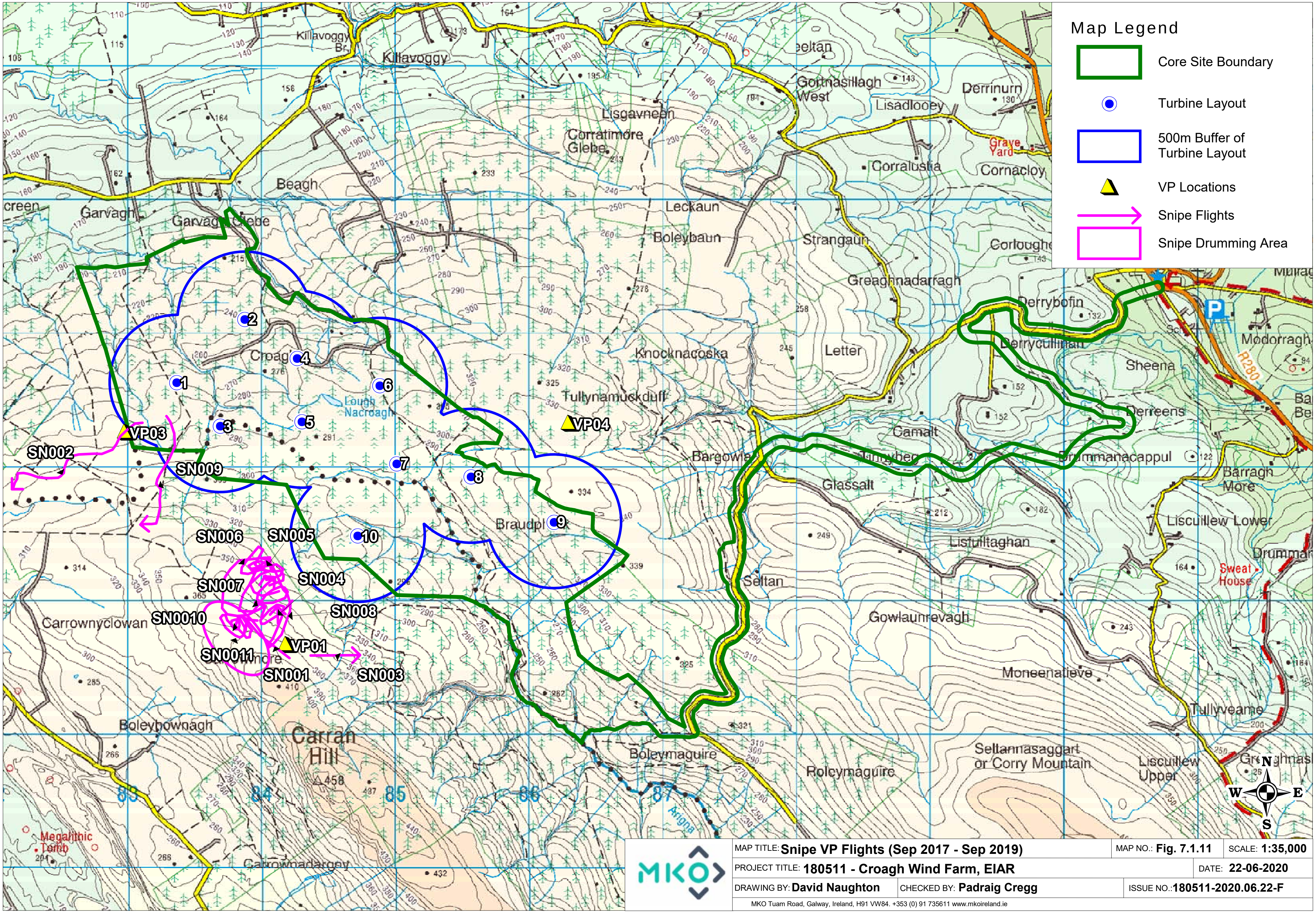

MAP TITLE: **Snipe VP Flights (Sep 2017 - Sep 2019)**		MAP NO.: **Fig. 7.1.11**	SCALE: **1:35,000**
PROJECT TITLE: **180511 - Croagh Wind Farm, EIAR**			DATE: **22-06-2020**
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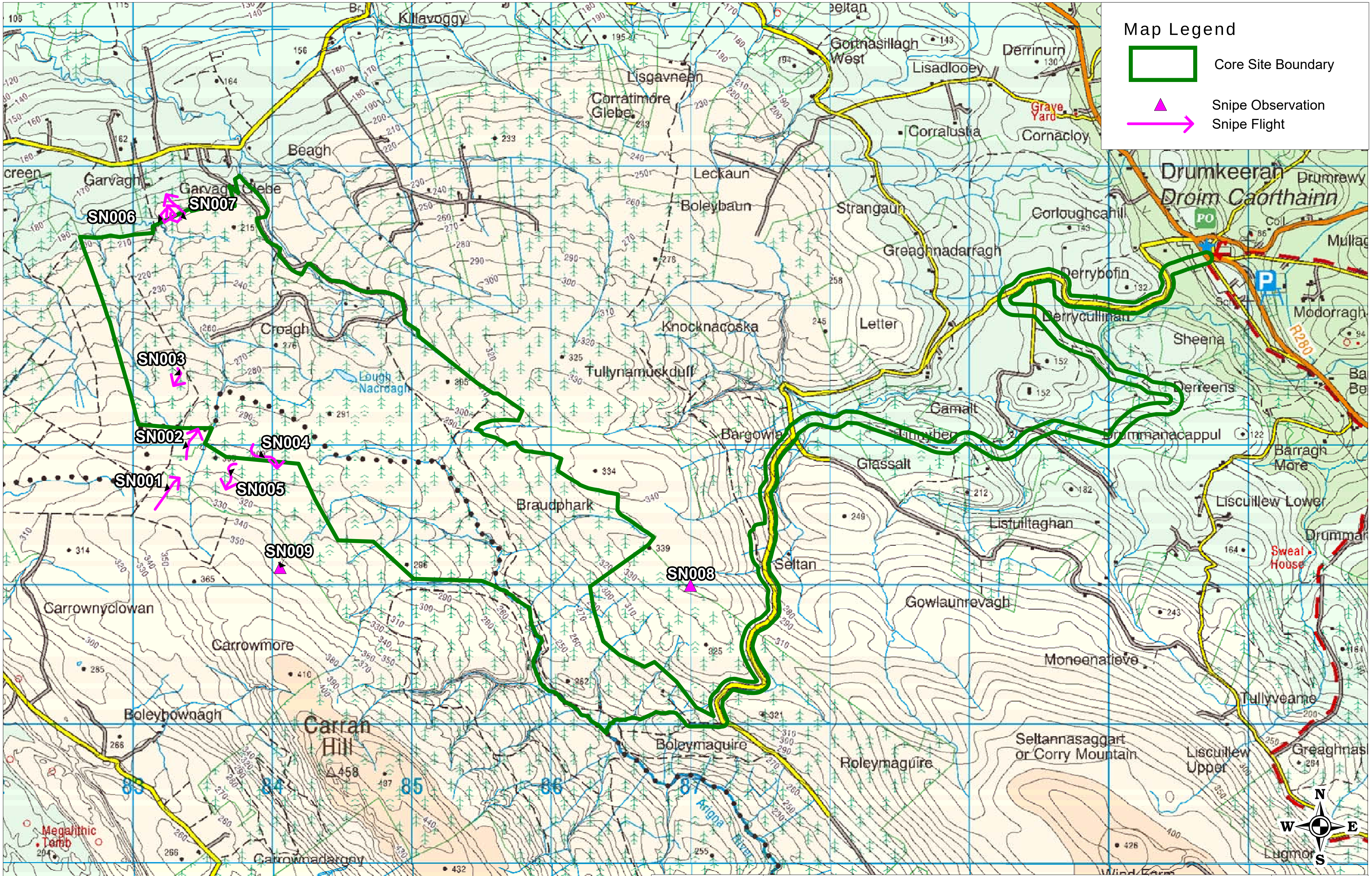

MAP TITLE: Snipe Breeding Bird Survey Observations		MAP NO.: Figure 7.3.6	SCALE: 1:35,000
PROJECT TITLE: 180511 - Croagh Wind Farm, EIAR			DATE: 22-06-2020
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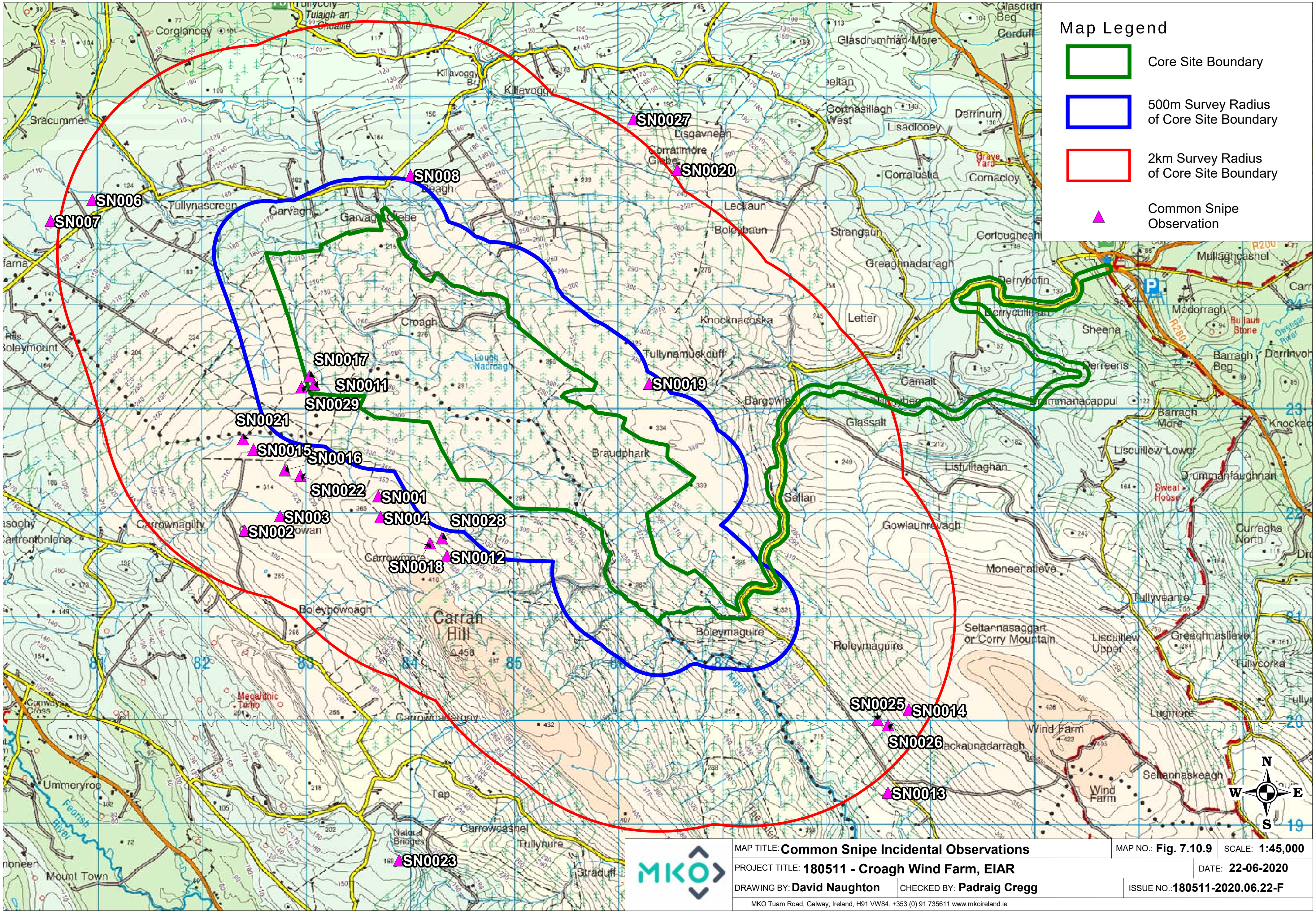
Map Legend
Core Site Boundary
500m Survey Radius of Core Site Boundary
2km Survey Radius of Core Site Boundary
Common Snipe Observation
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SN002
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Braudphark
Knocknacaska
Tullynamuckduff
Boleymaguire
Carrowmore
Boleybownagh
Garvagh
Leckaun
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Glassalt
Sheena
Derrybofin
Moneenatieve
Gowlaunrevagh
Lisfulltaghan
Wind Farm
MKO
MAP TITLE: Common Snipe Incidental Observations
MAP NO.: Fig. 7.10.9
SCALE: 1:45,000
PROJECT TITLE: 180511 - Croagh Wind Farm, EIAR
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APPENDIX 7-5

VANTAGE POINT NO.2 – SURVEY DATA

Appendix 7-5 – Additional Survey Data

Croagh Windfarm

DOCUMENT DETAILS

Client: **Coillte**

Project Title: **Croagh Windfarm**

Project Number: **180511**

Document Title: **Appendix 7-5 – Additional Survey Data**

Document File Name: **180511 – EIAR – 2019.09.19 – D1**

Prepared By:
MKO
Tuam Road
Galway
Ireland
H91 VW84

Planning and Environmental Consultants

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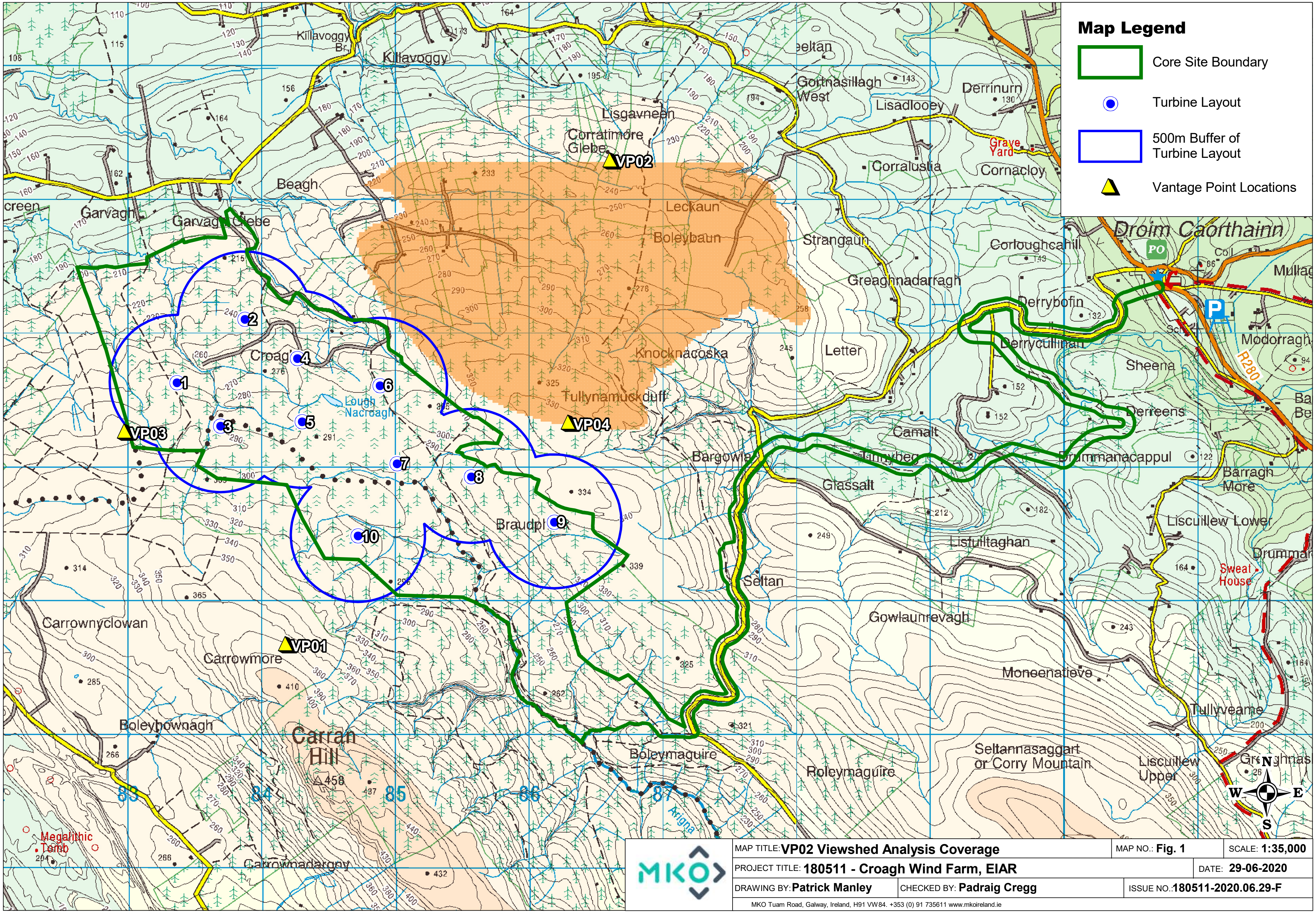
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Core Site Boundary
Turbine Layout
500m Buffer of Turbine Layout
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VP03
VP04
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Killavoggy Br.
Lisgavneen
Corratimore Glebe
Gortnasillagh West
Lisadlooey
Derrinurn
Grave Yard
Corralustia
Cornacloy
Beagh
Garvagh
Garvagh Glebe
Leckaun
Boleybaun
Strangaun
Droim Caorthainn
Corloughcahill
Greaghnadarragh
Derrybofin
Mullag
Croagh
Lough Nacroagh
Knocknacoska
Letter
Derrycullinan
Sheena
Modorragh
R280
Tullynamuckduff
Derreens
Camalt
Bargowla
Tullyhega
Drummanacappul
Barragh More
Glassalt
Braudpl
Liscuillew Lower
Listullaghan
Drummar
Sweat House
Seltan
Carrownyclowan
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MAP NO.: Fig. 1
SCALE: 1:35,000
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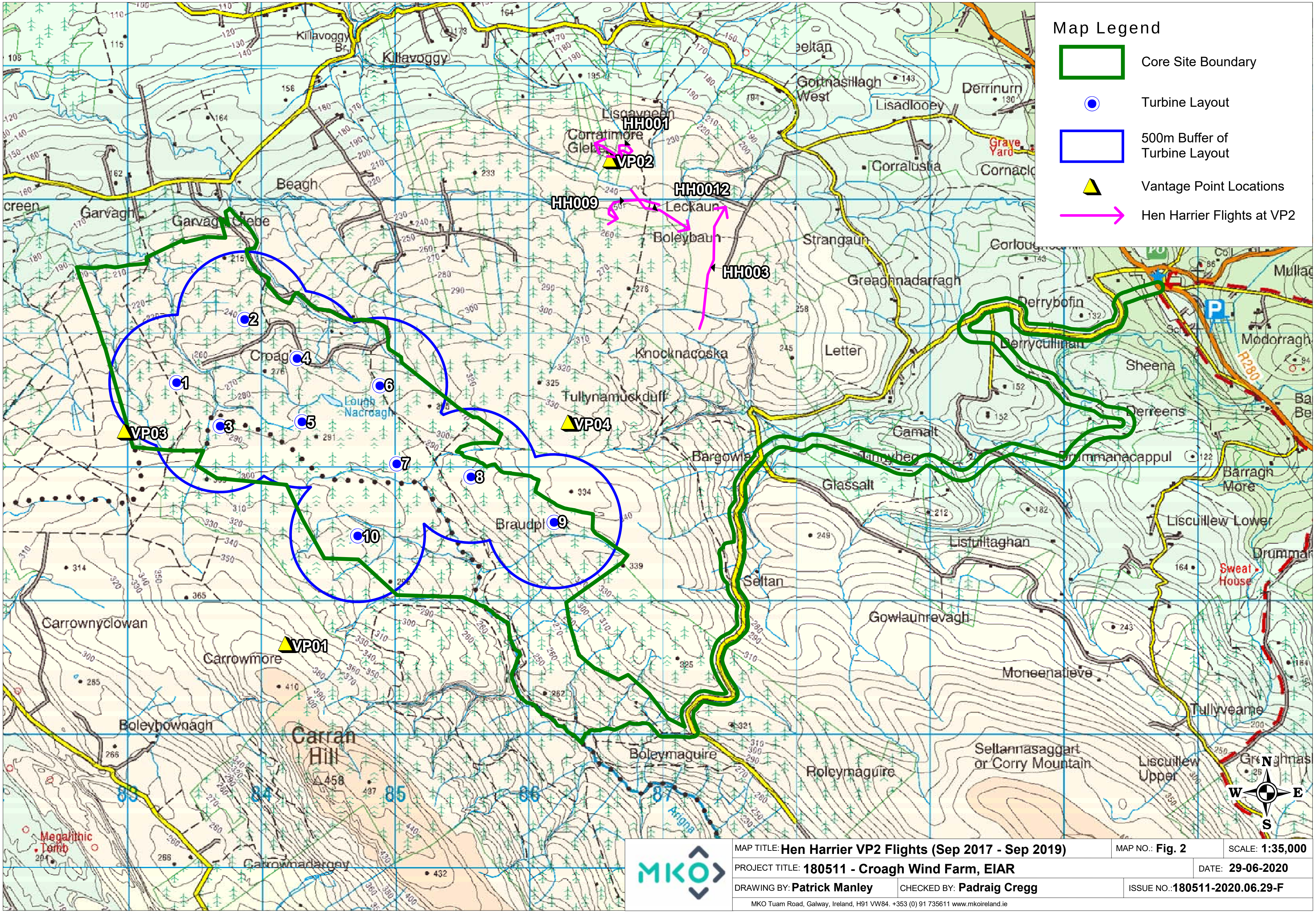
1. APPENDIX 7-5 (ADDITONIAL SURVEY DATA)

Table 1-1 Golden Plover VP2 Survey Data (Boleybaun)

Map Ref. No.	Date	VP	Species	No. of Birds	Time of flight	Notes on habitat and activity	Comments	Surveyor
N/A	14/11/2017	2	Golden Plover	1	15:17:00	HH1, (Dry siliceous heath) GS4, (Wet grassland) Calling	Golden Plover heard calling two or three times, around 100-150m south east of the VP in the heather.	LD
N/A	14/11/2017	2	Golden Plover	1	15:24:00	HH1, (Dry siliceous heath) GS4, (Wet grassland) Calling	Golden Plover heard calling again (9-11 secs) from the same area above. Approximate Grid Ref: G 8700 2505.	LD
N/A	07/11/2018	2	Golden Plover	1	07:10:00	PB4, (Cutover bog) Call heard of lone bird		JK

Table 1-2 Hen Harrier VP2 Survey Data (Boleybaun)

Map Ref. No.	Date	VP	Species	No. of Birds	Time of flight	Duration of flight (s)	Duration Within 500m Buffer of Site Boundary	Duration Outside	Band 1 (0-10m)	Band 2 (10-25m)	Band 3 PCH (25-175m)	Band 4 (>175m)	Notes on habitat and activity	Comments	Surveyor
HH001	22/02/2018	2	Hen Harrier	1	12:31:00	37			25	12			PB2, (Upland blanket bog) WD4, (Conifer plantation) Ringtail circled up over plantation finger at 5-20m before heading E out of sight	Ringtail	RW
HH003	04/05/2018	2	Hen Harrier	1	09:25:00	15			15				WD4, (Conifer plantation) in flight		SF
HH009	19/09/2018	2	Hen Harrier	1	14:00:00	50	50			50			PB2, (Upland blanket bog) hunting female/juv		DM
HH0012	03/09/2019	2	Hen Harrier	1	08:39:00	8	0	8		0	0		WD4, (Conifer plantation)	Juvenille HH flying low towards site	AOD



MAP TITLE: Hen Harrier VP2 Flights (Sep 2017 - Sep 2019)		MAP NO.: Fig. 2	SCALE: 1:35,000
PROJECT TITLE: 180511 - Croagh Wind Farm, EIAR			DATE: 29-06-2020
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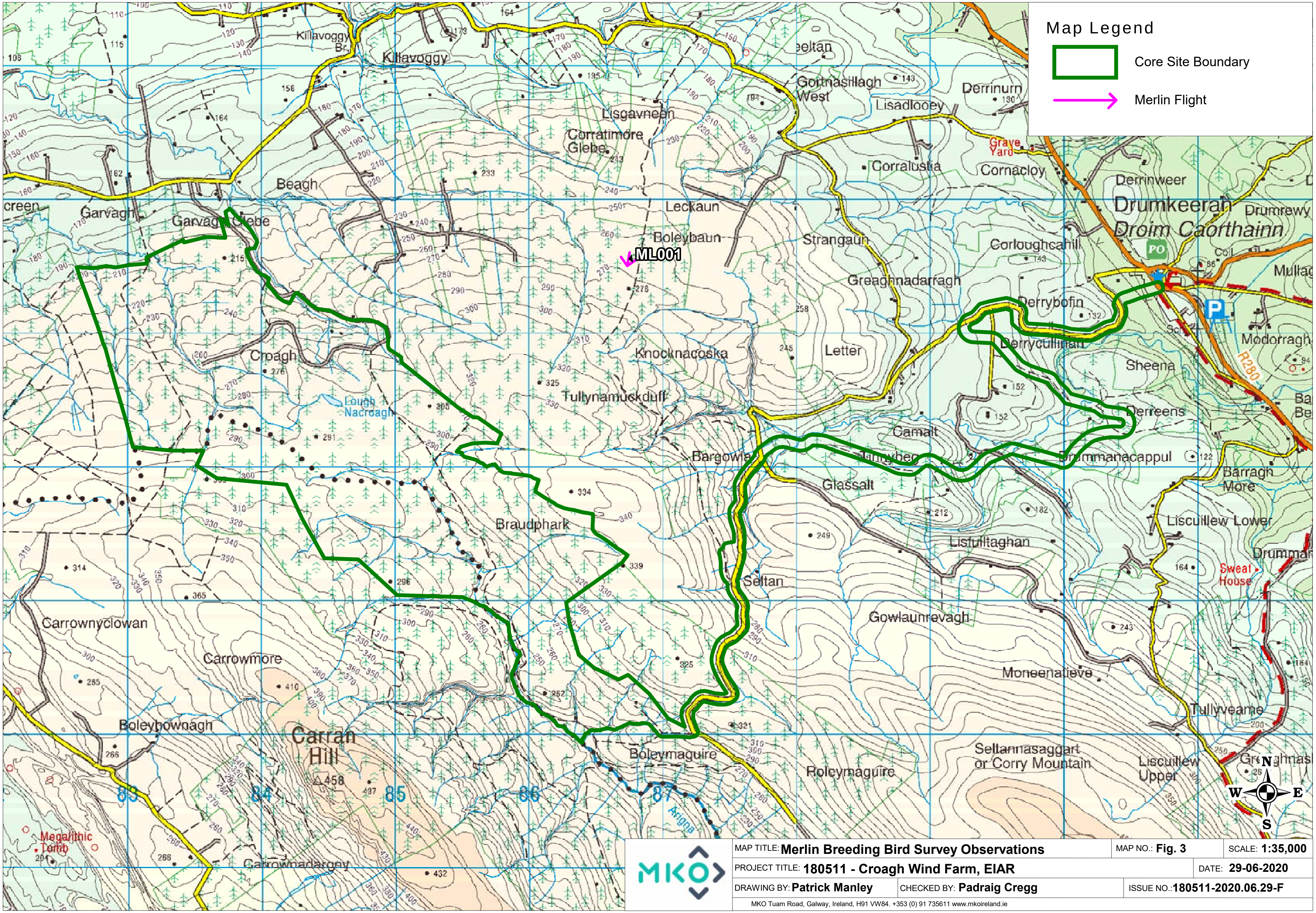
Table 1-3 Merlin Breeding Bird Survey Observation from Boleybaun Area

Map Ref. No.	Date	Transect/ Area	Species	No. of Birds	Time of flight	Duration of flight (s)	Notes on habitat and activity	Comments	Surveyor
ML001	06/05/2018		Merlin	1	08:32:00	5	GS4, (Wet grassland) WD4, (Conifer plantation) WS2, (Immature woodland) Flying into trees.	Possible Merlin seen flying low over heather, dense grass and immature conifers into a large conifer. Brief sighting (4-5 seconds) so cannot be certain as it flew south into the sun. Silhouette of a Falcon and suitable habitat at the edge of conifers, with open moorland adjacent for foraging.	LD



Map Legend

- Core Site Boundary
- Merlin Flight

MAP TITLE: Merlin Breeding Bird Survey Observations		MAP NO.: Fig. 3	SCALE: 1:35,000
PROJECT TITLE: 180511 - Croagh Wind Farm, EIAR			DATE: 29-06-2020
DRAWING BY: Patrick Manley	CHECKED BY: Padraig Cregg		ISSUE NO.: 180511-2020.06.29-F

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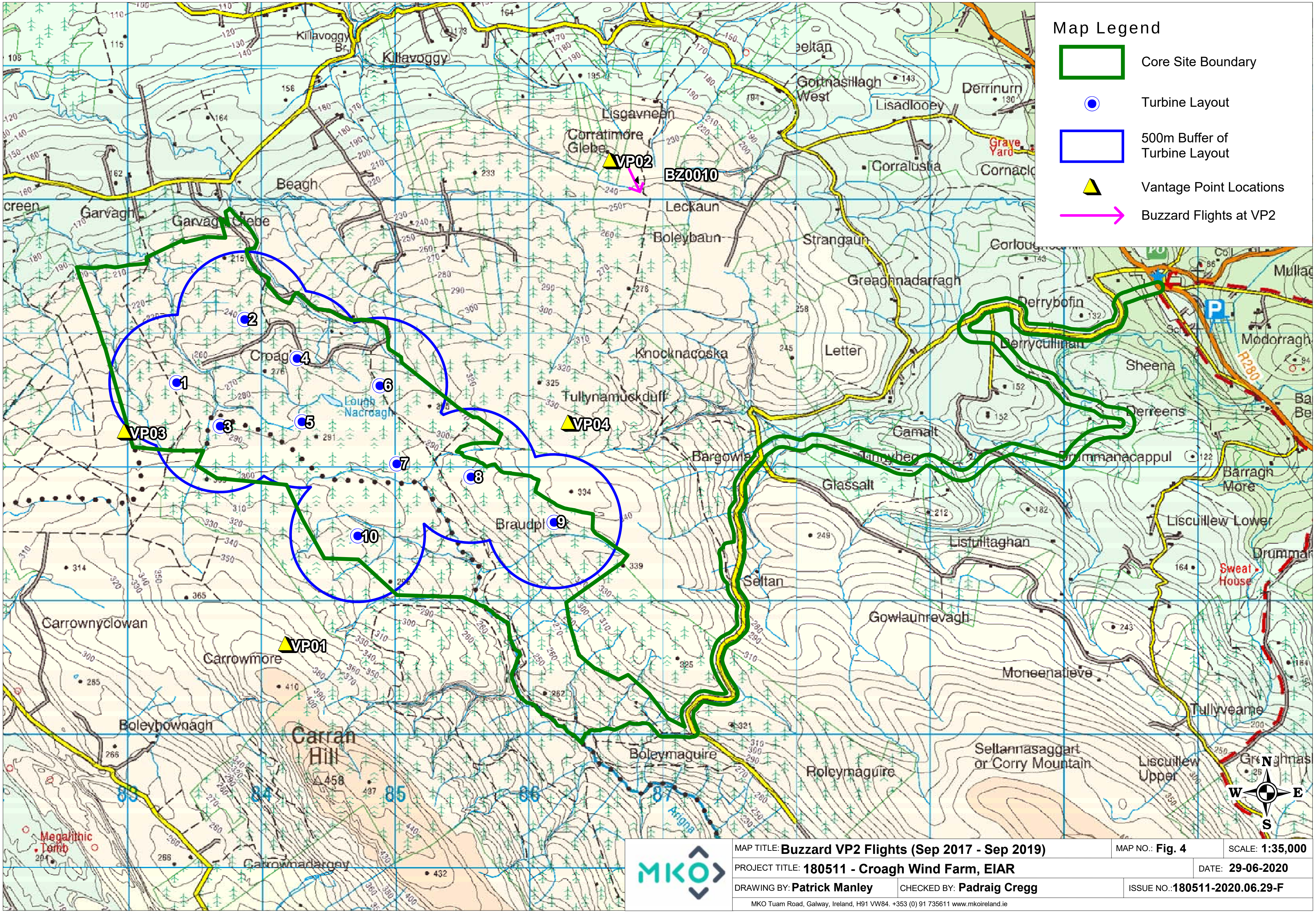
Table 1-4 Red Grouse VP2 Survey Data (Boleybaun)

Map Ref. No.	Date	VP	Species	No. of Birds	Time of flight	Notes on habitat and activity	Comments	Surveyor
N/A	17/05/2019	2	Red Grouse	1	04:48:00	HH4, (Montane heath) Calling male not seen		AOD

Table 1-5 Buzzard VP2 Survey Data (Boleybaun)

Map Ref. No.	Date	VP	Species	No. of Birds	Time of flight	Duration of flight (s)	Duration Within 500m Buffer of Site Boundary	Duration Outside	Band 1 (0-10m)	Band 2 (10-25m)	Band 3 PCH (25-175m)	Band 4 (>175m)	Notes on habitat and activity	Comments	Surveyor
BZ0010	12/06/2019	2	Buzzard	2	19:51:00	60		60			60		WD4, (Conifer plantation) Gliding over WD4 before disappearing behind treeline.		PW



MAP TITLE: **Buzzard VP2 Flights (Sep 2017 - Sep 2019)**	MAP NO.: **Fig. 4** / SCALE: **1:35,000**
PROJECT TITLE: **180511 - Croagh Wind Farm, EIAR**	DATE: **29-06-2020**
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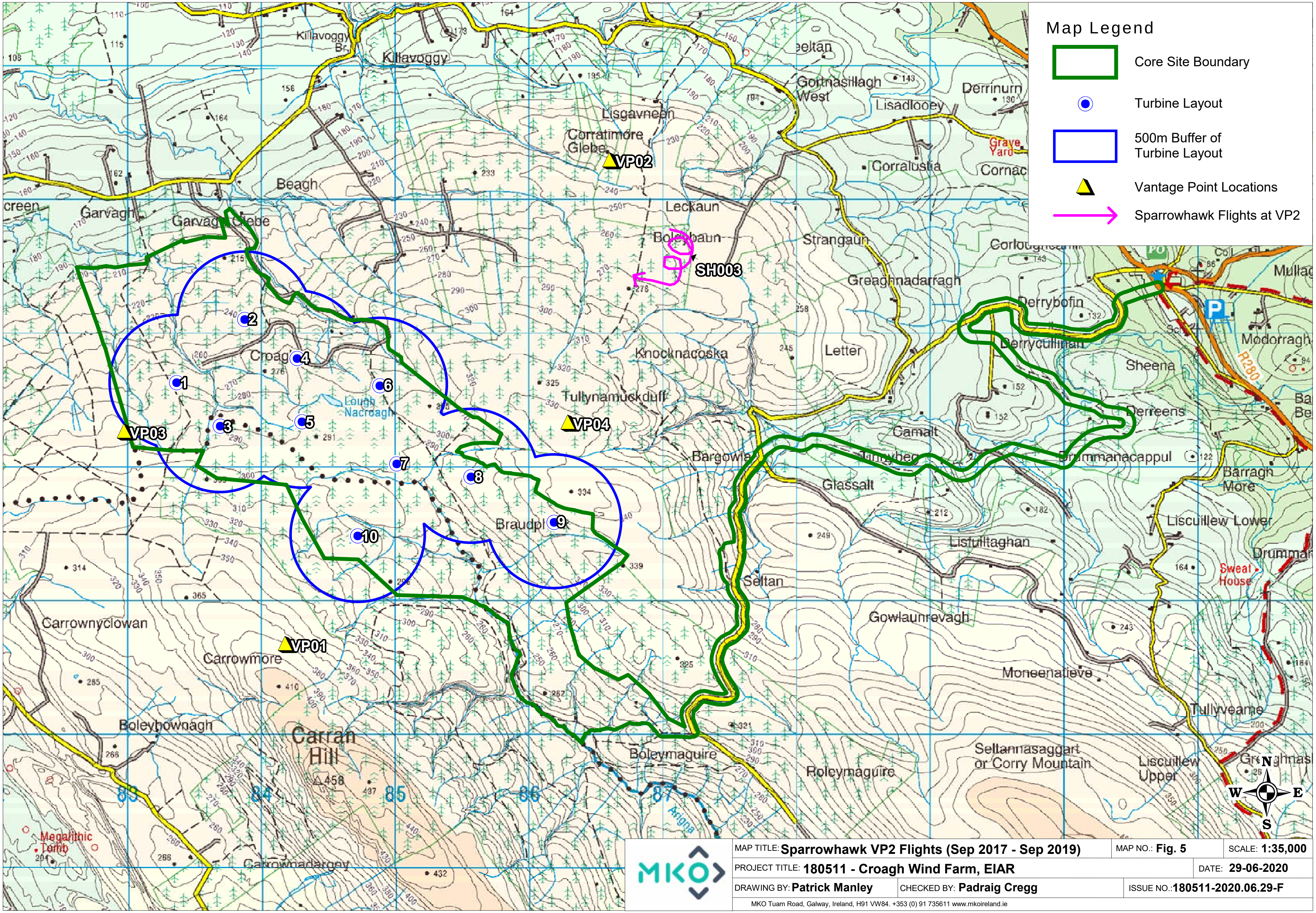
Table 1-6 Sparrowhawk VP2 Survey Data (Boleybaun)

Map Ref. No.	Date	VP	Species	No. of Birds	Time of flight	Duration of flight (s)	Duration Within 500m Buffer of Site Boundary	Duration Outside	Band 1 (0-10m)	Band 2 (10-25m)	Band 3 PCH (25-175m)	Band 4 (>175m)	Notes on habitat and activity	Comments	Surveyor
SH003	12/06/2019	2	Sparrowhawk	1	16:24:00	56	56			56			HH1, (Dry siliceous heath) WD4, (Conifer plantation) Soaring in thermal		PW



MAP TITLE: Sparrowhawk VP2 Flights (Sep 2017 - Sep 2019) | MAP NO.: Fig. 5 | SCALE: 1:35,000

PROJECT TITLE: 180511 - Croagh Wind Farm, EIAR | DATE: 29-06-2020

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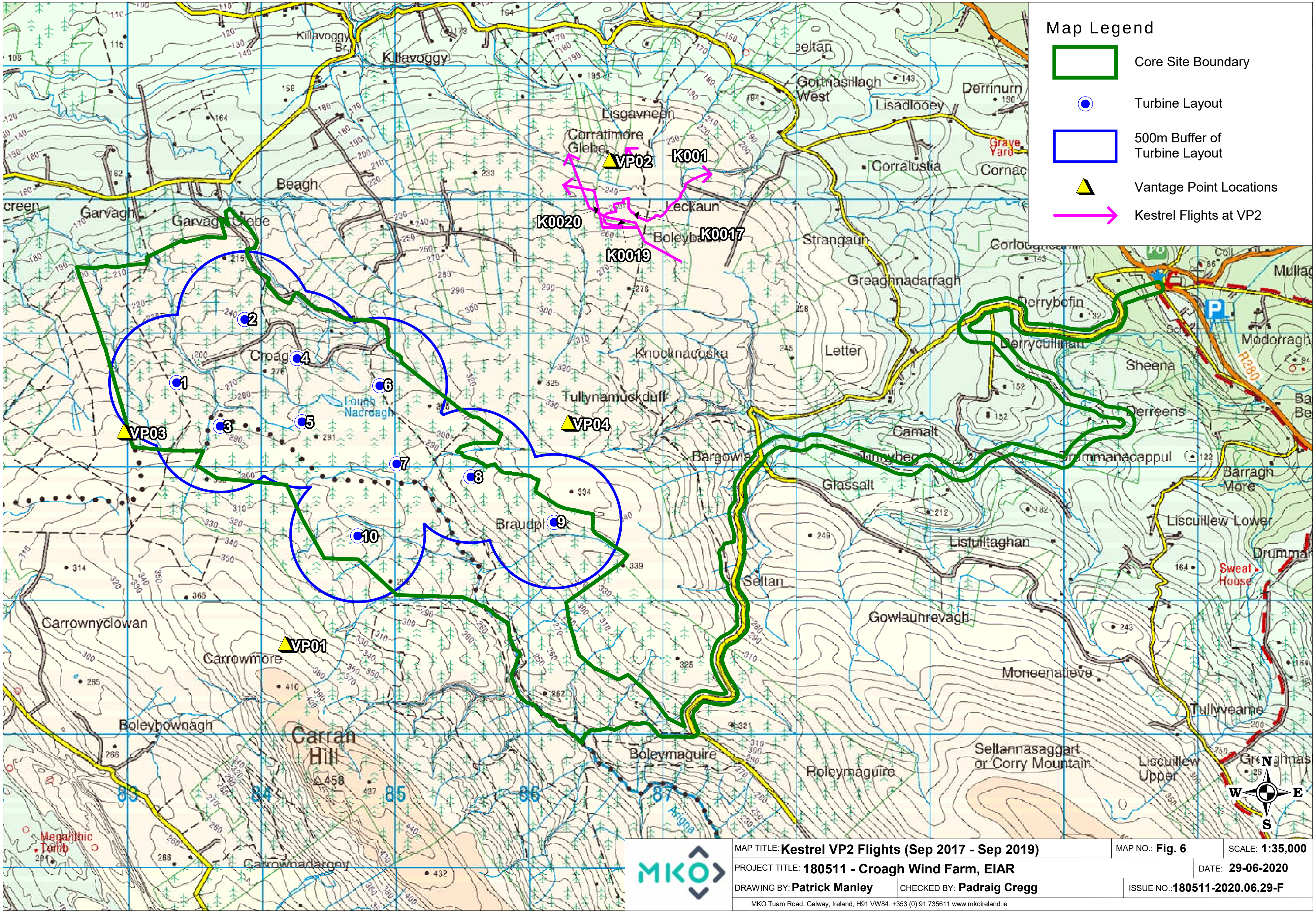
Table 1-7 Kestrel VP2 Survey Data (Boleybaun)

Map Ref. No.	Date	VP	Species	No. of Birds	Time of flight	Duration of flight (s)	Duration Within 500m Buffer of Site Boundary	Duration Outside	Band 1 (0-10m)	Band 2 (10-25m)	Band 3 PCH (25-175m)	Band 4 (>175m)	Notes on habitat and activity	Comments	Surveyor
K001	05/04/2018	2	Kestrel	1	10:45:00	50				50			PB2, (Upland blanket bog) WD4, (Conifer plantation)		SF
K0017	12/06/2019	2	Kestrel	1	16:58:00	471	460	11	25	221	225		HH1, (Dry siliceous heath) WD4, (Conifer plantation) Male K hunting/hovering over edge of forest and moorland came down to ground three times (marked as dot on map) before rising again and flying northeast.		PW
K0019	03/09/2019	2	Kestrel	1	11:43:00	360	0	360		340	0		HH1, (Dry siliceous heath) WD4, (Conifer plantation)	Adult female foraging flew north	AOD

Table 1-8 Kestrel Winter Transect Survey Observation from Boleybaun Area

Ref No.	Date	Transect/ Survey Area	Species	No. of Birds	Sex/Age	Time of observation	Habitat and Activity	Comments	Surveyor
K001	17/10/2018		Kestrel	1	ADULT FEMALE	16:30:00	PB2, (Upland blanket bog) WD4, (Conifer plantation)	HUNTING 30S BAND2, HOVERING	AOD



MAP TITLE: Kestrel VP2 Flights (Sep 2017 - Sep 2019)	MAP NO.: Fig. 6	SCALE: 1:35,000
PROJECT TITLE: 180511 - Croagh Wind Farm, EIAR		DATE: 29-06-2020
DRAWING BY: Patrick Manley	CHECKED BY: Padraig Cregg	ISSUE NO.: 180511-2020.06.29-F

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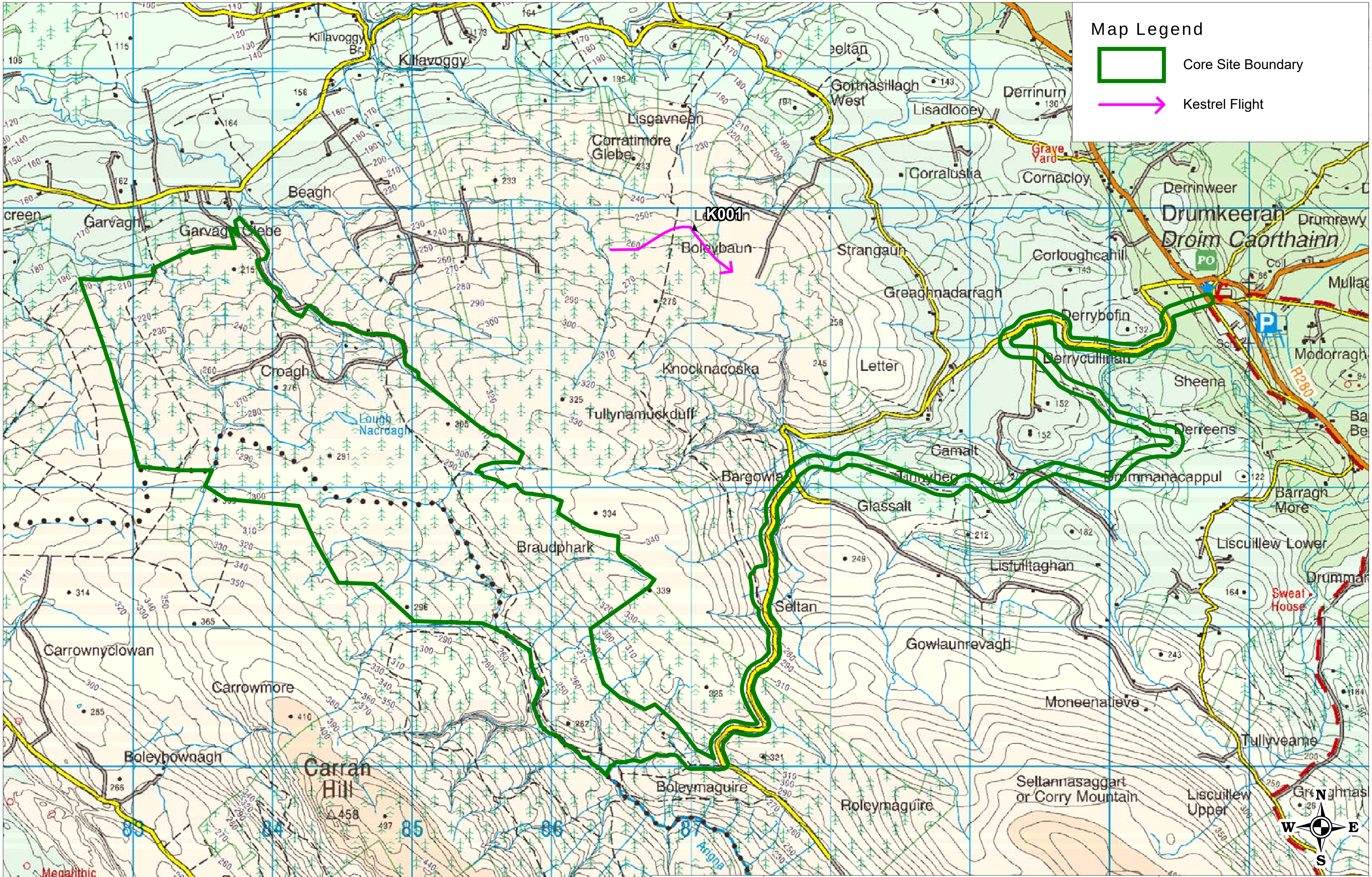

MAP TITLE: **Kestrel Winter Bird Survey Observations**

MAP NO.: **Fig. 7**

SCALE: **1:35,000**

PROJECT TITLE: **180511 - Croagh Wind Farm, EIAR**

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APPENDIX 7-6

COLLISION RISK MODELLING ASSESSMENT

Appendix 7-6 – Collision Risk Assessment

Croagh Wind Farm -

DOCUMENT DETAILS

Client: **Coillte**

Project Title: **Croagh Wind Farm -**

Project Number: **180511**

Document Title: **Appendix 7-6 – Collision Risk Assessment**

Document File Name: **180511 –CRA – 2020.07.06 – F**

Prepared By:
MKO
Tuam Road
Galway
Ireland
H91 VW84

Planning and Environmental Consultants

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1. INTRODUCTION

This document has been prepared by MKO to assess the collision risk for birds at the proposed Croagh Wind Farm Site, Co. Leitrim/Sligo. The collision risk assessment, prepared by Mr David Naughton (BSc), is based on vantage point watch surveys undertaken at the development site from September 2017 up to and including September 2019 covering a full two-year survey period, consisting of two breeding seasons and two non-breeding seasons, in full compliance with SNH (2017). Surveys were undertaken from three fixed Vantage Point (VP) Locations, (i.e. VP1, VP3 & VP4).

Collision risk is calculated using a mathematical model to predict the numbers of individual birds, of a particular species, that may be killed by collision with moving wind turbine rotor blades. The modelling method used in this collision risk calculation follows Scottish Natural Heritage (SNH) guidance which is sometimes referred to as the Band Model (Band et al. (2007)).

Two stages are involved in the model:

- Stage 1: Estimation of the number of birds or flights passing through the air space swept by the rotor blades of the wind turbines. Transits are calculated using either the "**Regular** or **Random Flight**" model, depending on flight distribution and behaviour.
- Stage 2: Calculation of the probability of a bird strike occurring. Calculated using a statistical spreadsheet which considers avian biometrics and turbine parameters. This spreadsheet is publicly available on the SNH website. https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision

The product of Stage 1 and Stage 2 gives a theoretical annual collision mortality rate on the assumption that birds make no attempt to avoid colliding with turbines.

The Band model has been the subject of academic assessment (e.g. Chamberlain et al., (2005 & 2006), Madders & Whitfield (2006), Drewitt & Langston (2006), Fernley, Lowther & Whitfield (2006)) and its results must be interpreted with a degree of caution.

An informal third stage is then applied to the generated outcome of Stage 1 and Stage 2. This third stage is to account for a "real life" scenario, i.e. to account for the avoidance measures taken by each bird species, worked out as percentage applied to the product of stage 1 and 2. This third "informal" stage is often the most important factor of collision risk modelling. For several years, SNH advocated a highly precautionary approach, recommending a value of 95% as an avoidance rate (Band et al., (2007)). However, based on empirical evidence and continuous studies and literature, precautionary rates have now been increased to 98-99% or higher in most cases and are regularly evolving with further examination of bird behaviour and mortality rates at windfarm sites. The most recently recommended species' avoidance rates can be found at https://www.nature.scot/wind-farm-impacts-birds-guidance-avoidance-rates-guidance.

2. METHODOLOGY

Two forms of collision risk modelling are considered when referencing the Band Model. These are often referred to as the **"Regular Flight Model"** and the **"Random Flight Model"**. The "Regular Flight Model" is generally applied to a suite of flightlines which form a regular pattern such as a commuting corridor between roosting and feeding grounds or migratory routes. As such the "Regular Flight Model" is typically relevant for waterbird species, particularly geese and swans. The "Random Flight Model" is relevant for scenarios whereby no discernible patterns or flight routes can be associated with a species within the study area. Random flights can occur for any species but is most prevalent when examining foraging or hunting flight behaviour.

- **"Random Flight Model"** examines the predicted number of transits through the windfarm by regarding all flights within the viewshed (i.e. a 2km of the vantage point) as randomly occurring. This model therefore assumes that any observed flight could just as easily occur within the windfarm site as without. Any flights recorded as flying within the rotor swept height inside the 2km arc of the vantage point is to be included in the model.
  This model has a number of key assumptions and limitations;

    1. *Bird activity is not spatially explicit, i.e. activity is equal throughout the viewshed area and this is equal to activity in the windfarm area.*
    2. *Habitat and bird activity will remain the same over time and be unchanged during the operational stage of the windfarm.*
    3. *The area of the view shed used in the analysis is a worst-case scenario, given it is calculated based on the lowest swept height.*
    4. *All flight activity recorded at potential collision risk height within the view shed of relevant VPs are used in the model.*

- **"Regular Flight Model"** examines the predicted number of transits through a cross-sectional area of the windfarm which represents the width of the commuting corridor. A 2-dimesional line represents a "risk window" which is the width of the windfarm plus a 500m buffer of the turbines, multiplied by the rotor diameter. All commuting flights which pass through this risk window, within the swept height of the turbines, are included in collision risk modelling. Any regular flights more than 500m from the turbine layout can be excluded from analysis.
  This model has a number of key assumptions and limitations;

    1. *Firstly, that the turbine rotor swept area is 2-dimensional, i.e. there is a single row of turbines in the windfarm. This represents all turbines within the commuting corridor accounted for by a single straight-line.*
    2. *It is assumed that bird activity is spatially explicit.*
    3. *Birds in an observed flight only cross the turbine area once and do not pass through the cross-section a second time (or multiple times).*

More detail on both the Random and Regular Flight Model calculations are publicly available and can be found on the SNH website. https://www.nature.scot/wind-farm-impacts-birds-calculating-theoretical-collision-risk-assuming-no-avoiding-action.

In the case of all species observed at Croagh, flights during the survey period could be classified as randomly distributed flights which could occur anywhere within the given viewsheds. Therefore the "Random Flight Model" was applied to these species to calculate the predicted number of transits through the windfarm site.

The steps used to derive the collision risk percentage for each species observed at the proposed development according to the Band Model are outlined below:

1. Stage 1 (Band): the model uses observations of birds flying through the study area during vantage point surveys to calculate the number of birds estimated to fly through the proposed turbines blade swept areas.

2. Stage 2 (Band): the model calculates the collision risk for an individual bird flying through a rotating turbine blade. The collision risk depends on the species biometrics and flight behaviour. Bird biometrics are available from the British Trust of Ornithology (BTO) online bird collision risk guidance, while flight speeds have been referenced from Alerstam et al. (2007).

3. The product of the number of birds calculated to fly through the turbines in a year multiplied by the collision risk (i.e. that a bird doing so will collide with the moving blades) gives the worst-case scenario for collision mortality. The worst-case scenario assumes that birds flying towards the turbines make no attempt to avoid them.

4. An avoidance factor is applied to the results to account for avoidance of the turbines by birds in flight. This corrects for the ability of the birds to detect and manoeuvre around the turbines. Avoidance rates are available from SNH online bird collision risk guidance (SNH 2018).

5. This final output after all steps to the model is a real-world estimation of the number of collisions that may occur at the wind farm based on observed bird activity during the survey period.

The Band Method makes a number of assumptions on the biometrics of birds and the turbine design. These are:

- Birds are assumed to be of a simple cruciform shape.
- Turbine blades are assumed to have length, depth and pitch angle, but no thickness.
- Birds fly through turbines in straight lines.
- Bird flight is not affected by the slipstream of the turbine blade.
- Because the model assumes that no action is taken by a bird to avoid collision, it is recognised that the collision risk figures derived are purely theoretical and represent worst case estimates.

Several assumptions were made in the calculation of collision risk for the proposed Croagh Windfarm. These assumptions are tailored specifically to Croagh and are as follows:

- Birds in flight within the study area at heights between 25m and 175m are assumed to be in danger of collision with the rotating turbine blades.
- Avoidance factors of individual species are those currently recommended by SNH (2018). An avoidance factor is applied to the results to account for avoidance of the turbines by birds in flight. This corrects for the ability of the birds to detect and manoeuvre around the turbines.
- No preference was taken for birds using flapping or gliding flight through the study area for species which exhibit both behaviours. In the calculation of the percentage risk of collision for a bird flying through a rotating turbine, the mean of the worst-case scenario (i.e. a bird flying upwind through a turbine using flapping flight whilst the turbine is at its fastest rotation speed) and the best-case scenario (i.e. a bird flying downwind through a rotating turbine using a gliding flight whilst the turbine at its slowest rotation speed) has been used for species which exhibit both flapping and gliding flight. Due to the nature of their flight activity, for species such as Swans and Geese only the mean calculations for flapping flights were used.

The Collision Risk Assessment (CRA) also makes assumptions on the turbine specifications, such as rotor diameter and rotational speed. Because the final choice of turbine will not be known until a competitive tendering process is complete, the worst-case scenario is assumed. The worst-case scenario is a combination of the maximum collision risk area (i.e. swept area determined by hub height and rotor blade length), maximum number of turbines proposed and turbine operational time. The turbine and wind farm characteristics for the purposes of this assessment at the proposed Croagh Windfarm Site are presented in Table 1.

Table 1 Windfarm Parameters at Croagh Wind Farm

Wind Farm Component	Scenario Modelled
Assumed turbine model	GE 3.6-137 Turbine
Number of turbines	10
Blades per turbine rotor (3d model used)	3
Rotor diameter (m)	140
Rotor radius (m)	70
Hub height (m)	100
Swept height (m)	30 - 170
*Mean pitch of blade (degrees)	25
Maximum chord (m) (i.e. depth of blade)	4.0
Max Tip Speed (M/S)	82
Circumference of Blade Tip (Pi*Rotor Diameter)	430.4
Rotational period (s) [430.4/82]	5.25
**Turbine operational time (%)	85%

****This operational period of 85% is referenced from a report by the British Wind Energy Association (BWEA) (2007) which identifies the standard operational period of the wind turbines in the UK to be roughly 85%.**

*Pitch of Blade used in the Analysis

It is acknowledged that pitch angle is determined by wind speeds which is something that is variable across seasons, and a range of geographical areas. The mean pitch of turbine blades has two referenced figures in Table 2.1 above. Wind speed versus the desired turbine rpm determines blade pitch. There is a specific pitch angle for any given wind speed to optimise output power. Typically speaking, the higher the wind speeds are, the higher the angle of the pitch.

This figure of 25 degrees is from Band (2012) where it is quoted that a standard figure for pitch for most large modern turbines would be between 25 – 30 degrees. This figure is considered highly precautionary however as the paper examines collision risk modelling for offshore windfarms, where windspeeds would be expected to be much higher than an on-shore windfarm site in Sligo/Leitrim.

3. RESULTS

Collison estimates were calculated using flight data recorded during vantage point watches at three vantage point locations (VP1, VP3 and VP4) within the study area between September 2017 and September 2019. The target species recorded within the potential collision risk zone included whooper swan, golden plover, hen harrier, merlin, buzzard, sparrowhawk, kestrel and snipe. It is acknowledged that the predicted number of transits, and hence predicted rate of collision for snipe may be largely underestimated, as flight activity for this species is largely crepuscular in nature while the VP survey sample consists of hours during daylight period for the most (Table 1.4, SNH (2017)).

The calculation parameters are outlined in Tables 2 – 8. A fully worked example of the calculation of collision risk for golden plover is available in Appendix 1.

Table 2 Croagh Windfarm VP Survey Effort and Viewshed Coverage

Vantage Point	Visible Area (hectares)	Risk Area (hectares)	Turbines visible from VP	Total Survey Effort (hrs)
VP1	522.9	275.2	5	153
VP3	545.4	271.5	6	153
VP4	402.1	247.9	6	153

Table 3 Bird Biometrics (Taken from BTO BirdFacts & Alerstam et al. (2007)) and duration at PCH during VP Surveys

Species	Length (m)	Wingspan (m)	Ave. speed (m/s)	Seconds in flight at PCH (25 - 175m)
Whooper Swan (Winter)	1.52	2.30	17.3	6,168
Golden Plover (Winter)	0.28	0.72	17.9	288,352
Hen Harrier	0.48	1.10	9.1	65
Merlin	0.28	0.56	10.1	15
Buzzard	0.54	1.20	13.3	1,401
Sparrowhawk	0.33	0.62	10.0	110
Kestrel	0.34	0.76	10.1	708
Snipe	0.26	0.46	17.1	1,173

Seconds in flight at PCH is calculated by multiplying the number of birds observed per flight by the duration of the flight spent within the height band 10-175m.

Table 4 Random CRM - Number of Transits per Turbine within the Viewshed of each VP

Species	VP1	VP3	VP4
Whooper Swan (Winter)	130.62	0	11.88
Golden Plover (Winter)	4,560.17	2,136.43	0
Hen Harrier	0.46	0.28	0

Species	VP1	VP3	VP4
Merlin	0	0.18	0
Buzzard	7.54	8.99	8.81
Sparrowhawk	0	0	1.82
Kestrel	0	7.44	1.74
Snipe	25.29	4.70	0

Table 5 Number of Transits across site per year (Averages calculated from Table 3.3 Above and adjusted for all ten turbines)

Species	Average Transits	Transits Across Entire Site (All 10 Turbines) (Average Transits*10)
Whooper Swan (Winter)	47.5	475.0
Golden Plover (Winter)	2,232.2	22,322.0
Hen Harrier	0.25	2.5
Merlin	0.06	0.6
Buzzard	8.5	84.5
Sparrowhawk	0.6	6.1
Kestrel	3.1	30.6
Snipe	10.0	100.0

Table 6 Collision Risk Workings (Both Flapping and Gliding Flights took the average Collision Risk Percentage between upwind and downwind)

Species	Flapping Flight	Gliding Flight	Collision Risk [(Flapping + Gliding)/2]
Whooper Swan	9.3%	N/A	9.3%
Golden Plover	4.9%	N/A	4.9%
Hen Harrier	9.4%	9.3%	9.35%
Merlin	7.4%	7.3%	7.33%
Buzzard	7.2%	7.0%	7.1%
Sparrowhawk	7.7%	7.7%	7.7%
Kestrel	7.7%	7.7%	7.7%
Snipe	4.9%	N/A	4.9%

*Table 7 Collision Probability assuming no Avoidance (Transits*Collision Risk)*

Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Whooper Swan	9.3%	475.0	44.06
Golden Plover	4.9%	22,322.0	1,101.58
Hen Harrier	9.35%	2.5	0.23
Merlin	7.33%	0.6	0.05
Buzzard	7.1%	84.5	5.96
Sparrowhawk	7.7%	6.1	0.47
Kestrel	7.7%	30.6	2.36
Snipe	4.9%	100.0	4.86

Table 8 Collision Probability using Avoidance Rates outlined in SNH (September 2018 V2)

Species	Collisions /year	Collisions /30 Years	Avoidance factor (%)	Note
*Whooper Swan	0.220	6.6	99.5%	Winter/Passage (Oct-Mar)
*Golden Plover	22.03	660.9	98%	Winter/Passage (Oct-Mar)
Hen Harrier	0.002	0.07	99%	All year
Merlin	0.0009	0.03	98%	All year
Buzzard	0.119	3.58	98%	All year
Sparrowhawk	0.009	0.28	98%	All year
Kestrel	0.118	3.53	95%	All year
*Snipe	0.097	2.92	98%	All year

*Assumed to be active 25% of the night as well as daylight hours per SNH guidance accounting for Swan/Geese and Wader activity. This is calculated as a portion of the length of night for the survey period provided by www.timeanddate.com and is added to available hours for activity of the species per year.

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https://www.timeanddate.com/sun/

APPENDIX 1

WORKED EXAMPLE OF COLLISION RISK CALCULATION (RANDOM FLIGHT MODEL) – GOLDEN PLOVER

Stage 1 (Transits through rotors per year) [Using figures from VP1 Column]

Table 9 Standard Measurements (Specific to Golden Plover, Windfarm Site, Turbines modelled & VP1)

Description	Value	Units
Survey area visible from VP (Hectares) [At 30m]	Avp	522.9
Survey Time at VP1 over both winter periods (secs)	s	290,412
Bird observation time at 25-175m (secs)	PCH	194,626
Rotor Radius (metres)	r	70
Rotor Diameter (metres)	D	140
Max chord width of turbine blade (metres)	d	4.0
No. of turbines in viewshed of VP1	x	5
Bird length in metres (golden plover) [Taken from BTO online)	l	0.28
Ave. Flight speed of golden plover (m/s) [Allerstam et al. 2007]	v	17.9
500m buffer of turbines within viewshed, i.e. Area of Risk (Hectares)	Arisk	275.2
Availability of species activity during survey period (hours) [Daylight hours + 25% of night during survey period]	Ba	5,907.73

Table 10 CRM Stage 1 Calculations using Standard Measurements in Table 1

Description	Value	Formula	Units
Proportion of time between 25-175m	t1	s/PCH	0.670172031
Flight activity per visible unit of area	F	t1/Avp	1.28E-03
Proportion of time in risk area	Trisk	F*Arisk	0.3527086
Bird occupancy of risk area	n	Trisk*Ba	2083.70736
Risk volume (Area of risk*Rotor Diameter)	Vw	(Arisk*D)*10,000	385280000
Actual volume of air swept by rotors	o	X*(Pi*r2(d+l))	329427.4057
Bird occupancy of rotor swept area (seconds)	b	3600*(n*(o/Vw))	6413.904471
Time taken for bird to pass through rotors (seconds)	t2	(d+Bl)/v	0.239106145
Number of bird passes through the rotor in the survey period	N	b/t2	26824.50702

Description	Value	Formula	Units
Total transits adjusted for max annual Turbine Operation Time (85% in this case)	Tn	N*0.85	22800.83
Number of transits per turbine within viewshed of VP1	**TnT1**	**Tn/x**	**4560.17**

Table 11 CRM Stage 1 Calculations – Number of transits through windfarm

Description	Value	Formula	Units
Number of transits per turbine with viewshed of VP1	**TnT1**	**Tn/x**	**4560.17**
Number of transits per turbine with viewshed of VP3	TnT2	Tn/x	2136.43
Number of transits per turbine with viewshed of VP4	TnT3	Tn/x	0
Average transits per turbine for all VPs	ATnT	(TnT1+TnT2+TnT3) /3	2232.20
Predicted number of transits through windfarm site (All ten turbines)	T	ATnT*10	22321.98182

Transits through rotors for the species in a one-year period across the site

22,322

Stage 2 (Collision Probability)

Calculation of the probability of the birds colliding with the turbine rotors:

The probability of a bird colliding with the turbine blades when making a transit through a rotor depends on a number of estimated factors. These factors include the avoidance factor 98% – the ability of birds to take evasive action when coming close to wind turbine blades.

In the calculations, the length of a golden plover was taken to be 0.28 metres and the wingspan 0.72 metres. The flight velocity of the bird is assumed to be 17.9 metres per second. The maximum chord of the blades is taken to be 4.0 metres, variable pitch is assumed to be 25 degrees and the average rotation cycle is taken to be 5.25 seconds per rotation, depending on wind conditions.

A probability, ρ (r, ϕ), of collision for a bird at radius r from the hub and at a position along a radial line that is at angle ϕ from the vertical is calculated. This probability is then integrated over the entire rotor disc, assuming that the bird transit may be anywhere at random within the area of the disc. Scottish Natural Heritage (SNH) have made available a spreadsheet to aid the calculation of these probabilities. For a full explanation of the calculation methods see Band et al. (2007). The results of these calculations for all species are shown in Table 3-7.

Collision Probability*

4.9%

*This is calculated using the SNH collision risk probability model at https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision

Collisions per year

The annual theoretical collision rate assuming no avoidance = Transits (T)*Collision probability

1,101.6

The annual theoretical collision rate assuming 98% avoidance (1,101.6*0.02)

22.03

Theoretical collision rate assuming 98% avoidance across the 30-year duration of the windfarm (22.03*30)

660.9

APPENDIX 7-7

BIRD MONITORING PROGRAMME

Appendix 7-7 – Bird Monitoring Programme

Croagh Wind Farm

DOCUMENT DETAILS

Client:	**Coillte**
Project Title:	**Croagh Wind Farm**
Project Number:	**180511**
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Document File Name:	**180511 – BMP - 2020.03.04 – F**
Prepared By:	**MKO** **Tuam Road** **Galway** **Ireland** **H91 VW84**

MKO Planning and Environmental Consultants

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1. INTRODUCTION

This Bird Monitoring Programme has been prepared by MKO for the proposed Croagh Wind Farm, Co. Leitrim/Sligo.

This document provides a timeframe and monitoring schedule for the bird population of the study area during the post-construction phase of the project. Breeding and wintering bird surveys were undertaken during the period September 2017 to September 2019 encompassing two full breeding seasons and two full winter seasons, as well as autumn and spring migration periods, in line with SNH guidance on recommended bird survey methods to inform impact assessment for onshore wind energy developments (SNH, 2017). The surveys undertaken to date have informed the various proposed bird monitoring measures outlined in this document.

1.1 Key Ornithological Receptors and Birds of Conservation Concern

Table 1 lists the Key Ornithological Receptors recorded within the study area during field surveys.

Table 1 Key Ornithological Receptors identified during field surveys undertaken at the Croagh Community Wind Farm

Common Name	Latin Name	Conservation Status
Whooper Swan	*Cygnus cygnus*	Annex I; EU Birds Directive,
Golden Plover	*Pluvialis apricaria*	Annex I; EU Birds Directive, BoCCI Red List & Irish Wildlife Act
Hen Harrier	*Circus cyaneus*	Annex I; EU Birds Directive; BoCCI Amber List & Irish Wildlife Act.
Merlin	*Falco columbarius*	Annex I; EU Birds Directive; BoCCI Amber List & Irish Wildlife Act.
Red Grouse	*Lagopus lagopus*	BOCCI Red Listed with regard to Breeding Populations
Woodcock	*Scolopax rusticola*	BOCCI Red Listed with regard to Breeding Populations
Buzzard	*Buteo buteo*	Raptor Species; Schedule 4 of the Wildlife Act 1976
Sparrowhawk	*Accipiter nisus*	Raptor Species; Schedule 4 of the Wildlife Act 1976
Kestrel	*Falco tinnunculus*	Raptor Species; Schedule 4 of the Wildlife Act 1976
Snipe	*Gallinago gallinago*	BoCCI Amber Listed, Bio-indicator Species for Hen Harrier

1.3 Objectives

This document has been prepared having regard to the following objectives:

- To ensure any required pre-commencement/ pre-construction phase monitoring is scheduled to ensure any impacts on breeding birds are avoided.
- To record usage of the site by birds and interaction with operating turbines during the post-construction phase of the development.
- To monitor short-term and long-term effects on bird populations with a particular emphasis on wintering and breeding birds deemed to be of high conservation concern (Annex I; EU Birds Directive and BoCCI red list species).
- To undertake collision monitoring and corpse searches for potential bird fatalities as a result of collision with turbine blades.
- Report on findings of post construction monitoring at the end of each monitoring year (Year 1, 2, 3, 5, 10 & 15 of the life time of the wind farm).

2.1 Methodology

2.2 Pre-construction Bird Monitoring

It is proposed that construction works will commence outside the bird nesting season (1st of March to 31st of August inclusive) to avoid the most sensitive time of the year for most bird species with the potential to use the site and its environs. Pre-commencement surveys will be undertaken prior to the initiation of works at the wind farm.

A breeding bird survey will be undertaken between April and July. Monitoring will be undertaken by a suitably qualified ornithologist. The survey will include a thorough walkover survey to a 500m radius of the development footprint and/or all works areas, where access allows. If breeding activity of birds of high conservation concern is identified, the nest site will be located, and earmarked for monitoring at the beginning of the first breeding season of the construction phase. If it is found to be active during the construction phase no works shall be undertaken within a 500m buffer (Forestry Commission Scotland 2006; Ruddock & Whitfield 2007) in line with best practise. No works shall be permitted within the buffer until it can be demonstrated that the nest is no longer occupied.

All site staff and subcontractors will be made aware of any restrictions to be imposed by means of a toolbox talk and a map of the 'no-work zone' will be made available to all construction staff. The restricted area will also be marked off using hazard-tape fencing to alert all personnel on site to the suspension of works within that area.

2.3 Post-construction Bird Monitoring

Survey methods employed for post-construction monitoring will be in line with guidelines issued by the Scottish Natural Heritage (SNH, 2009). Post-construction monitoring will be undertaken in Years 1, 2, 3, 5, 10 and 15 of the life time of the wind farm.

Post-construction monitoring will include ongoing breeding bird surveys, winter surveys and a programme of regular corpse searching of birds that may potentially collide with operating turbines during the operational phase of the wind farm project.

Bird monitoring will include the following survey methods:

- Vantage Point Surveys
- Distribution & Abundance Surveys (Particular focus on breeding and wintering hen harrier and upland breeding waders)
- Targeted bird collision surveys (corpse searches) will be undertaken. The surveys will include detection and scavenger trials, to correct for these two biases and ensure the resulting data is robust.

Vantage Point Surveys

Vantage point surveys will be undertaken monthly during operational years 1, 2, 3, 5, 10 and 15 of the life time of the wind farm. Methodology for vantage point watches will follow guidelines issued by the SNH (2009) & SNH (2017). The proposed vantage point watches will adhere to a minimum of 36 hours/VP during the breeding survey season as per guidelines issued by SNH. Monthly visits will be undertaken during monitoring years. During each visit, six-hour vantage point watches will be undertaken from a fixed vantage point location that offers an un-interrupted view of the study area. Vantage points will be undertaken from the same locations that pre-planning surveys which informed the EIAR application of the proposed development (i.e. VP1, VP3, VP4). Vantage point surveys will be timed to provide a spread over the full daylight period including dawn and dusk watches to coincide with the highest periods of bird activity. Behavioural categories for the observation of bird interactions with operational wind farms will be in line with terminology outlined by Meredith et al., (2002).

Distribution & Abundance Surveys

During the breeding season, post-construction distribution & abundance surveys will incorporate a combination of Adapted Brown & Shepherd surveys and transect surveys (Bibby et al., 2000) as well as Breeding Raptor surveys within 2km of the development site with a particular emphasis on breeding hen harrier (Hardey et al., 2013). Survey methodology will be similar to methods employed for baseline EIAR surveys which will allow a comparison of data to be made for each monitoring year.

During Adapted Brown & Shepherd surveys and transect surveys within 500m, particular attention will be paid to upland breeding waders (e.g. curlew) as well as breeding hen harrier, although all bird species and breeding activity will be recorded. The standard approach for surveying upland breeding waders is outlined in Brown and Shepherd (1993) and Gilbert et al. (1998). On site surveys will consist of the surveyors walking a route within quadrats which will have been selected to survey all suitable habitat types on site and to a 500m radius from the development/planning boundary (where access allows). Quadrat coverage should be such that every point of suitable habitat (on site and to a 500m radius) should be surveyed to within 100m. Surveyors should spend 20-25 minutes in each 500 x 500m quadrat (or field). Four visit will be timed to coincide with the core survey period April – July during monitoring years. Notes will be recorded on nesting and territorial behaviour and breeding signs using standard BTO codes. Non-breeding behaviour such as birds flying over the site will also be recorded.

In addition, shortened vantage point watches will be undertaken within 2km of the development site, in areas of suitable breeding habitat, to survey for breeding raptors within the wider area (e.g. hen harrier) in line with Hardey et al., (2013). Aural and visual registrations will be recorded during field surveys.

Hen Harrier Roost Surveys

As recommended by Gilbert et al (1998), hen harrier roost surveys will be undertaken during the winter season (October – March). Survey work will be undertaken in accordance with methods devised by Hardey et al. (2013) and the 'Irish Hen Harrier Winter Roost Survey' (unpublished document coordinated by members of NPWS). Surveys will take place on a monthly basis between October and March. The surveys will focus on area of potential winter roosting habitat within a 2km radius of the proposed development area.

2.3 Collision Searches (Bird Casualties)

Surveys for bird casualties will follow survey methods broadly based on guidelines issued by the Scottish Natural Heritage (2009) and search methods adopted by Duffy & Steward, 'Turbine Search Methods and Carcass Removal Trials at the Braes of Doune Windfarm' (Natural Research Information Note 4. Natural Research Ltd, Banchory, UK, 2008).

It is proposed to undertake a minimum of one visit per month during each survey year. During each visit, searches will be undertaken at each operating turbine location by a team of two surveyors. A plot measuring 130m x 130m from the centre of each turbine location will be the subject of targeted searches for bird casualties. Searches will incorporate the use of transects spaced at 10m intervals apart with the observer covering 5m on either side for each transect. Locations and coordinates of transect routes will be confirmed using a portable GPS recording device. Recording sheets will be used to document bird carcasses encountered in the field.

Alternatively, a trained dog and handler may be used where possible to locate any carcasses.

The following details will be considered during field surveys: GPS location of each bird carcass, photographic record, carcass condition (intact (carcass that is completely intact or not badly composed), scavenged (evidence that the carcass was fed upon by a scavenger/predator) or feather spot (ten or more feathers indicating predation or scavenging or two or more primary feathers must be present to consider the carcass a casualty)), distance from the turbine location, date, time, etc.

Corpse searching work will be calibrated to account for the ability to find bird corpses and likelihood of scavenging of corpses by animals. This will ensure a more accurate estimation of the total number of collision victims. To allow for this, sample bird corpses of various bird sizes will be placed within the various habitats found within proximity of the turbine locations. Carcasses will be left out in the trial areas by one worker and searched for by another two days later. A 36-hour period between laying carcasses and searching for them will help to prevent disturbance from discouraging scavengers from attending the trial plots. The locations of all carcasses will be logged using GPS by the layer and the finder. Any signs of scavenging will be recorded. Birds will be left in place for a further two weeks before a further examination will occur in order to determine further scavenging levels. The level of scavenging which occurs will then be used to help calibrate the detection rate and estimate a likely percentage of collisions that may be removed by scavengers between searches.

Results of bird casualties will be issued in a final report at the end of each monitoring year.

3. TIMEFRAME OF PROPOSED MONITORING WORKS

It is proposed to undertake bird monitoring surveys during years 1, 2, 3, 5, 10 & 15 of the wind farm operation.

Table 2 below describes the proposed bird monitoring work schedule for each monitoring year for the proposed wind farm development

Table 2 Proposed bird monitoring work schedule for each monitoring year at the Croagh Wind Farm

Survey Type	Phase	Period	No. of Visits	Survey Method
Vantage Point Surveys	Year 1, 2, 3, 5, 10 & 15	January - December	3 visits / month	Three fixed, 6-hour, Vantage Point Surveys
Distribution & Abundance Survey (Breeding Season)	Year 1, 2, 3, 5, 10 & 15	April - July	4 visits / monitoring year	Adapted Brown & Shepherd Survey/Walked transect/Raptor VP Survey
Hen Harrier Roost Surveys	Year 1, 2, 3, 5, 10 & 15	October - March	6 visits / month	Hardey et al. (2013) and the 'Irish Hen Harrier Winter Roost Survey' (unpublished document coordinated by members of NPWS)
Corpse Searches (Bird Casualties)	Year 1, 2, 3, 5, 10 & 15	January - December	1 visit/month for each monitoring year	Targeted corpse searches at turbine bases

4. REPORTING

A report summarising the findings of the bird monitoring surveys will be submitted to the Planning Authority, where required, within three months of each monitoring year. This will provide details of the various methods employed, the results of field surveys (vantage point watches, corpse searches, distribution and abundance surveys), potential effects/impacts on birds and any recommendations that may inform additional mitigation measures during the operational phase of the wind farm project.

Maps outlining flight lines of key target species will be produced using GIS software applications to accompany the final report at the end of each monitoring year.

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APPENDIX 8-1

GEOTECHNICAL & PEAT STABILITY ASSESSMENT REPORT

GEOTECHNICAL & PEAT STABILITY ASSESSMENT REPORT FOR CROAGH WIND FARM, CO. LEITRIM/SLIGO

McCarthy Keville O'Sullivan

JUNE 2020

Geotechnical & Peat Stability Assessment Report for Croagh Wind Farm, Co. Leitrim/Sligo

McCarthy Keville O'Sullivan

User is Responsible for Checking the Revision Status of This Document

Rev. Nr.	Description of Changes	Prepared by:	Checked by:	Approved by:	Date:
0	Issued to client for comment	GK	IH	BdH	4 Dec 19
1	Reissued to include delivery route and change to met mast location.	IH	PJ	BdH	19 Mar 20
2	Updates following Client comments	IH	PJ	BdH	21 May 20
3	Amended access road	IH	PJ	BdH	19 Jun 20

Client: McCarthy Keville O'Sullivan

Keywords: Geotechnical, Peat Stability, Peat Failure, Ground Investigation, Risk Assessment

Abstract: Fehily Timoney and Company (FT) were engaged by McCarthy Keville O'Sullivan to undertake a geotechnical assessment of the proposed Croagh wind farm site with respect to peat stability. As part of the geotechnical assessment of the proposed development, FT completed walkover surveys at the site and a ground investigation comprising 27 no. trial pits and 4 no. boreholes with associated laboratory testing was also carried out. The findings of the geotechnical and peat stability assessment showed that the site has an acceptable margin of safety and is suitable for the proposed wind farm development.

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1 NON-TECHNICAL SUMMARY

Fehily Timoney and Company (FT) formerly Applied Ground Engineering Consultants Ltd (AGEC) were engaged by McCarthy Keville O'Sullivan to undertake a geotechnical assessment of the proposed Croagh wind farm site with respect to peat stability. In accordance with planning guidelines compiled by the Department of the Environment, Heritage and Local Government (DoEHLG), where peat is present on a proposed wind farm development, a peat stability assessment is required.

The findings of the peat assessment, which involved analysis of 324 no. locations, showed that the proposed development areas have an acceptable margin of safety and that the site is suitable for the proposed wind farm development. The findings include recommendations and control measures for construction work in peat lands to ensure that all works adhere to an acceptable standard of safety.

The proposed wind farm comprises 10 no. wind turbines with associated infrastructure including access roads (new and upgrading of existing roads), substation, temporary construction compounds, met mast, borrow pit, repository areas and underground cabling and grid connection route.

The site is typically covered in blanket peat with undulating terrain. Up to 11.1km of existing tracks are present on the site and have been in operation for a number of years. Peat depths vary across the site depending on mainly topography. Peat depths recorded within the proposed infrastructure envelope ranged from 0 to 6m with an average of 2.1m. Peat depths recorded across the site from over 850 no. peat depth probes ranged from 0 to 8.2m with an average of 2.2m. The deeper peat areas were avoided when optimising the wind farm layout and main infrastructure elements for site.

Ground conditions typically comprised peat overlying soft silt/clay overlying glacial till overlying bedrock.

The peat depths recorded at the turbine locations varied from 0.3 to 4.5m with an average depth of 2.0m. The slope angle at the turbine locations range from 2 to 12 degrees, locally up to 12 degrees where the peat depth is shallow.

Numerous walkovers including intrusive peat depth probing and strength testing, a ground investigation including trial pits and boreholes, desk study, stability analysis and risk assessment was carried out to assess the susceptibility of the site to peat failure following the principles in Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments (PLHRA, 2017).

The purpose of the stability analysis undertaken was to determine the stability i.e. Factor of Safety (FoS), of the peat slopes. The FoS provides a direct measure of the degree of stability of a peat slope. A FoS of less than 1.0 indicates that a slope is unstable; a FoS of greater than 1.0 indicates a stable slope. An acceptable FoS for slopes is generally taken as a minimum of 1.3.

Based on the stability assessment carried out on the peat slopes the calculated FoS's are acceptable. The risk assessment at each of the main infrastructure locations includes mitigation/control measures to ensure the continued stability of the site.

The findings of the peat assessment, which involved analysis of 324 no. locations, showed that the proposed development areas have an acceptable margin of safety and that the site is suitable for the proposed wind farm development. Notwithstanding the above, there is an elevated risk of developing such a site in an area with a high density of historical landslides. The management of peat stability and appropriate construction practices will be inherent in the construction phase of the wind farm to ensure peat failures do not occur on site. Overall, the peat characteristics and ground conditions on the Croagh site are similar to that encountered on successfully developed wind farm sites in the area. In summary, the findings of the geotechnical and peat stability assessment showed that the proposed Croagh wind farm site has an acceptable margin of safety and is suitable for wind farm development.

2 INTRODUCTION

2.1 Background and Experience

Fehily Timoney and Company (FT) formerly Applied Ground Engineering Consultants Ltd (AGEC) were engaged in August 2018 by McCarthy Keville O'Sullivan (MKO) to undertake a geotechnical assessment of the proposed wind farm site with respect to peat stability.

FT/AGEC have been involved in over 100 wind farm developments in both Ireland and the UK at various stages of development i.e. preliminary feasibility, planning, design, construction and operational stage and have established themselves as one of the leading engineering consultancies in peat stability assessment, geohazard mapping in peat land areas, investigation of peat failures and site assessment of peat.

The proposed development site is located on the boundary of Counties Leitrim and Sligo, adjacent to the village of Drumkeeran and 7.3km southeast of Dromahair.

The site is within the northwest part of the Lough Allen upland, which typically comprises plateau and ridges with steep sides separated by valleys. The approximate development area for the site is 6.7km^2. A number of existing wind farm developments are located in close proximity to the site.

The proposed wind farm will comprise 10 no. turbines with a tip height of up to 170 metres and all associated foundations and hardstanding areas, access roads including upgrade of existing site roads and provision of new roads, 1 no. onsite electrical substation, excavation of 1 no. borrow pit, underground electrical and communications cabling connecting the turbines to the proposed onsite substation, underground cabling connecting the onsite substation to the existing Garvagh substation, 2 no. temporary construction compounds, 1 no. permanent anemometry mast, recreational car park, trails and signage, site drainage and all associated works.

A number of walkover surveys of the site were carried out by FT/AGEC between 2017 and 2020. The peat depth data previously recorded by FT/AGEC will be used in the assessment of peat stability for the proposed wind farm.

A number of walkover surveys of the site were also carried out by MKO, Hydro Environmental Services (HES) and Coillte between 2017 and 2020. The peat depth data recorded by MKO and HES during these walkover surveys was also used in the assessment of peat stability for the proposed wind farm.

In addition to the above, a ground investigation comprising 44 no. trial pits and 4 no. boreholes with associated laboratory testing was also carried out at the site. A further 6 no. trial pits were excavated along the proposed turbine delivery route in 2020.

2.2 Peat Stability Assessment Methodology

FT undertook the assessment following the principles in Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments (2nd Edition, PLHRA, 2017). The Peat Hazard and Risk Assessment is used in this report as it provides best practice methods to identify, mitigate and manage peat slide hazards and associated risks in respect of consent applications for electricity generation projects.

The best practice guide was originally produced following peat failures in the Shetland Islands, Scotland in September 2003 but more pertinently following the peat failure in October 2003, during the construction of a wind farm at Derrybrien, County Galway, Ireland.

The geotechnical assessment of peat stability at the proposed site included the following activities:

(1) Desk study

(2) Site walkover findings including shear strength and peat depth measurements

(3) Interpretation of ground investigation data (trial pits and boreholes)

(4) Overview of ground conditions and summary of ground investigation works carried out at the site

(5) Peat stability assessment of the peat slopes on site using a deterministic and qualitative approach

(6) Peat contour depth plan – based on peat depth probes carried out across the site by FT/AGEC, MKO and HES

(7) Factor of safety plan – is compiled for the short-term critical condition (undrained) for 324 no. FoS points analysed across the site

(8) Construction buffer zone plan – identifies areas with an elevated or higher construction risk where mitigation/control measures will need to be implemented during construction to minimise the potential risks and ensure they are kept within an acceptable range. In addition, the plan identifies areas on site where no development is advised

(9) A peat stability risk register is compiled to assess the potential design/construction risks at the infrastructure locations and determine adequate mitigation/control measures for each location to minimise the potential risks and ensure they are kept within an acceptable range, where necessary

(10) Comparison of site conditions with known failed sites

(11) Summary of the main implications of the soft deposits underlying the peat

(12) Indicative founding depths and details for the turbine foundations and other infrastructure elements

(13) Conclusions & recommendations

A flow diagram showing the general methodology for peat stability assessment is shown in Figure 2-1. The methodology illustrates the optimisation of the wind farm layout based on the findings from a site walkover and subsequent feedback from the peat stability and risk assessment results.

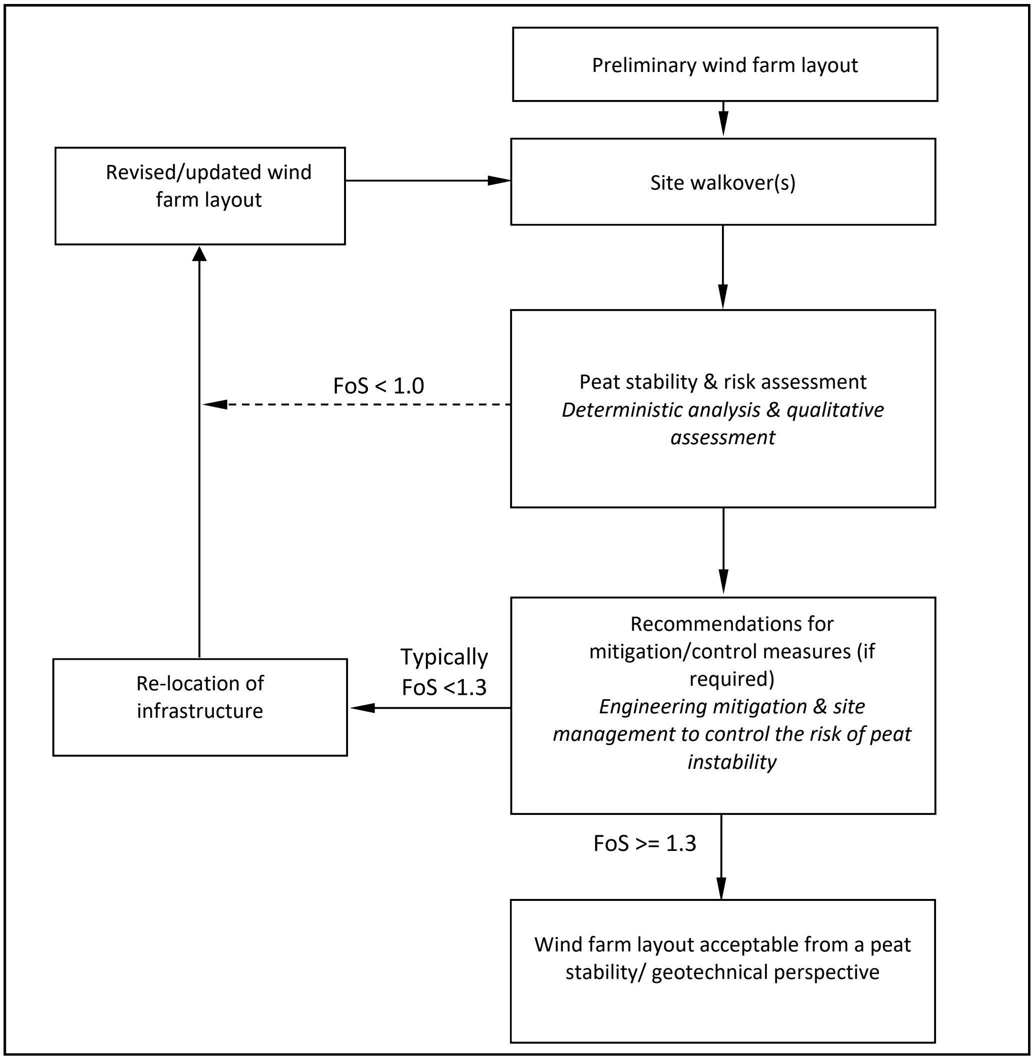

Figure 2-1: Flow Diagram Showing General Methodology for Peat Stability Assessment

2.3 Peat Failure Definition

Peat failure in this report refers to a significant mass movement of a body of peat that would have an adverse impact on proposed wind farm development and the surrounding environment. Peat failure excludes localised movement of peat that would occur below an access road, creep movement or erosion type events.

The potential for peat failure at this site is examined with respect to wind farm construction and associated activity.

2.4 Main Approaches to Assessing Peat Stability

The main approaches for assessing peat stability for wind farm developments include the following:

(a) Geomorphological

(b) Qualitative (judgement)

(c) Index/Probabilistic (probability)

(d) Deterministic (factor of safety)

Approaches (a) to (c) listed above are subjective and do not provide a definitive indication of stability; in addition, a high level of judgement/experience is required which makes it difficult to relate the findings to real conditions. FT apply a more objective approach, the deterministic approach (as discussed in Section 2.5).

As part of FT's deterministic approach, a qualitative risk assessment is also carried out taking into account qualitative factors, which cannot necessarily be quantified, such as the presence of mechanically cut peat, quaking peat, bog pools, sub peat water flow, slope characteristics and numerous other factors. The qualitative factors used in the risk assessment are compiled based on FT's experience of assessments and construction in peat land sites and peat failures throughout Ireland and the UK. This approach takes into account guidelines for geotechnical/peat stability risk assessments as given in PLHRA (2017) and MacCulloch (2005).

The risk assessment uses the results of the deterministic approach in combination with qualitative factors, which cannot be reasonably included in a stability calculation but nevertheless may affect the occurrence of peat instability to assess the risk of instability on a peat land site.

2.5 Peat Stability Assessment – Deterministic Approach

The peat stability assessment is carried out across a wide area of peatland to determine the stability of peat slopes and to identify areas of peatland that are suitable for development; this allows the layout of infrastructure on a particular wind farm site to be optimised. The assessment provides a numerical value (factor of safety) of the stability of individual parcels of peatland. The findings of the assessment discriminate between areas of stable and unstable peat, and areas of marginal stability where restrictions may apply. This allows for the identification of the most suitable locations for turbines, access roads and infrastructure.

A deterministic assessment requires geotechnical information and site characteristics which are obtained from desk study and site walkover, e.g. properties of peat/soil/rock, slope geometry, depth of peat, underlying strata, groundwater, etc. An adverse combination of the factors listed above could potentially result in instability. Using the information above a factor of safety is calculated for the stability of individual parcels of peatland on a site (as discussed in section 8).

The factor of safety is a measure of the stability of a particular slope. For any slope, the degree of stability depends on the balance of forces between the weight of the soil/peat working downslope (destabilising force) and the inherent strength of the peat/soil (shear resistance) to resist the downslope weight, see Figure 2-2.