# Derrybrien Wind Farm Project

## Gort Windfarms Ltd.

# Remedial Environmental Impact Assessment Report
# Chapter 11 - Hydrology and Hydrogeology
# Appendix 11A – Flood Risk Assessment

Document No.: QS-000280-01-R460-001-000

Date: July 2020

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# Project Location and Setting

The boundaries of the Derrybrien Wind Farm Project area on a regional scale lie almost entirely in the Kinvara Water Management Unit (637 $km^2$ area) within the Western River Basin District (RBD) (hydrometric area 29). A small area (<0.02 $km^2$) to the north-east corner of the wind farm site lies within the neighbouring Shannon Upper and Lower Water Management Unit within the Shannon International RBD (IRBD) (Figure 1).

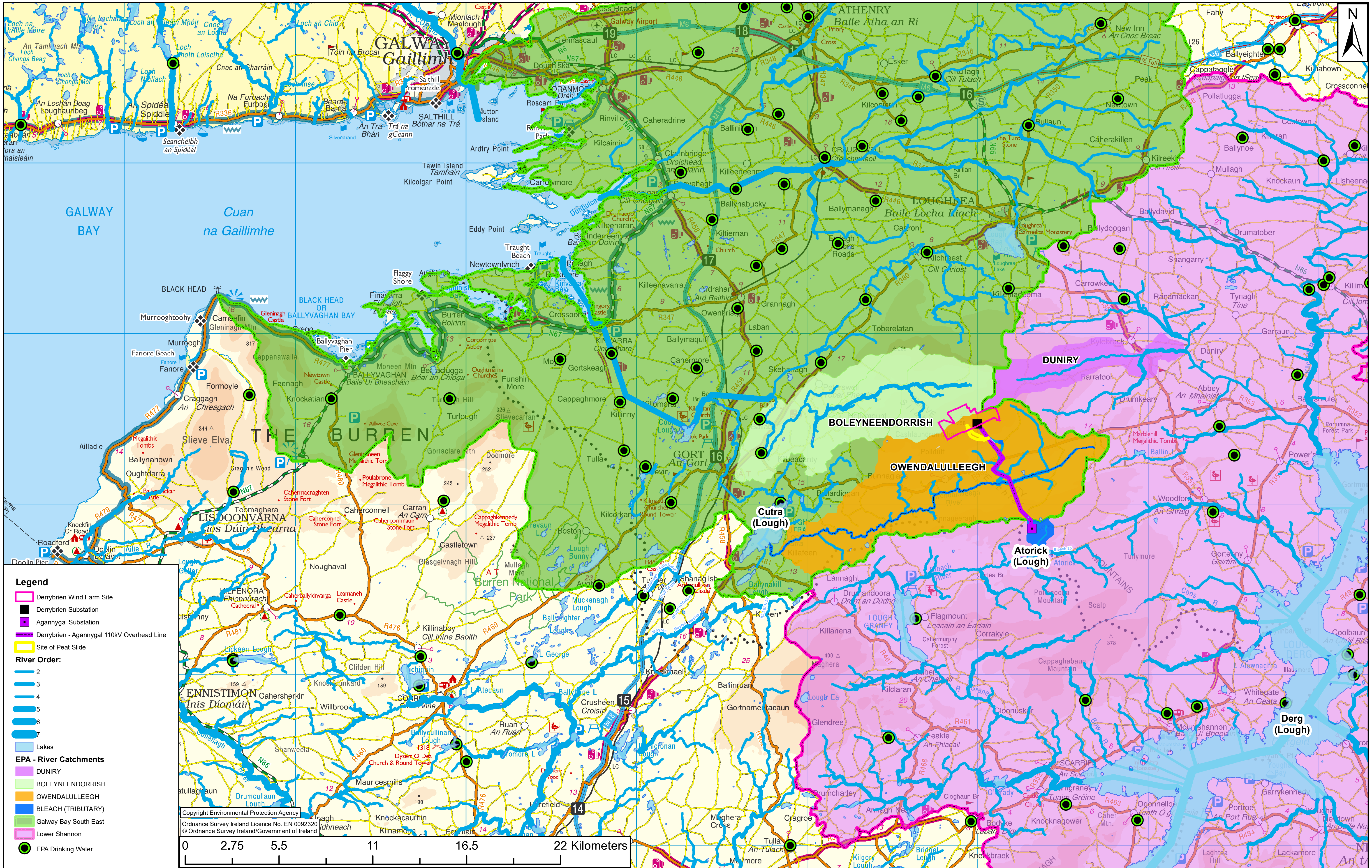
Derrybrien Wind Farm lies on Cashlaundrumlahan Mountain in the northern part of the Slieve Aughty Mountains in south County Galway, 12.7 km east-northeast of Gort, 12.7 km due south of Loughrea and 25 km west of Portumna. The lands within the wind farm site comprise disturbed peat bog, all of which was formerly used either for commercial Coillte forestry plantation (263 ha) or turbary bog lands (81 ha). The overall area of the wind farm site is approximately 344 ha (3.44 $km^2$) but the wind farm infrastructure comprises approximately 5% of the site area in terms of tracks, turbine bases and access areas). Site elevations range from 320–365 mOD on the upper slopes forming the wind farm, which form a gently sloping plateau aligned on a northeast to southwest axis. Slopes range from less than 3 – 7.5 degrees locally up to 10 degrees in places (Figure 2). There is a broad zone that runs across the full width of the site for a distance of approximately 250 – 300 m to the north and south of the peak of the mountain where the ground surface slopes gently away from the peak at slope angles of less than 3 degrees. This is within the central three rows of turbines. To the south of this zone the slope is convex in profile with slopes generally increasing up to 4 – 5 degrees and locally 5.0 – 7.5 degrees within the site boundary, particularly between Turbines T21 and T41. In general, the depth of peat is inversely proportional to the slope angles, i.e. peat is deeper across the middle of the site and shallower around the boundaries.

Downslope from the site in this area the slopes increase up to 7.5 degrees more consistently and locally up to 10.0 degrees. The peat slide during construction occurred within this zone of locally steeper slopes between Turbines T68 and T70.

The full site had been comprehensively drained in the past, prior to any wind farm construction, by a series of parallel open ditches to facilitate peat production and forestry. The ditches and drains in the worked bog and forestry discharge to the natural surface drainage lines and watercourses in the area (Plate 1 and Plate 2). Turf cutting (peat harvesting) has and continues to take place on the eastern part of the site. Farming is also undertaken in the lower lying areas away from the site. The principal economic activity in the immediate area is forestry and farming, the latter being dominated by grazing of cattle.

The roads on site prior to the wind farm project generally follow an east-west axis parallel to contours. The road layout of the wind farm also generally followed an east-west orientation with a number of spur roads connecting these from north to south, including along the internal boundary of the wind farm site.

In addition to the wind farm site, the study area also comprises the corridor of the 7.7 km overhead line running southward from the wind farm site and the grid connection substation at Agannygal connecting the wind farm to the National Grid (Figure 3). The elevation along the route falls to a flat-bottomed valley where it crosses the R353 road and the tributaries of the Owendalulleegh River at an elevation of approximately 130 mOD. From here, the route skirts around the Slieve Aughty Bog Natural Heritage Area (NHA, site number 001229) before

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PURPOSE OF ISSUE - PRELIMINARY UNLESS INDICATED

CLIENT APPROVAL ☐ PLANNING ☒ TENDER ☐ CONSTRUCTION ☐ AS-BUILT ☐

ESB Energy for generations

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CLIENT: Gort Windfarms Ltd

PROJECT: Derrybrien Wind Farm Project

CONTRACT:

PRODUCTION UNIT: Civil & Environmental Engineering

DRAWING TITLE: Appendix 11A - Figure 1 - Catchments in relation to Derrybrien Wind Farm Project



| DRAWN | PRODUCED | VERIFIED | APPROVED | APPROVAL DATE |
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| E.O'Shea | E.O'Shea | H.Griffin | P.Kavanagh | 13/07/2020 |

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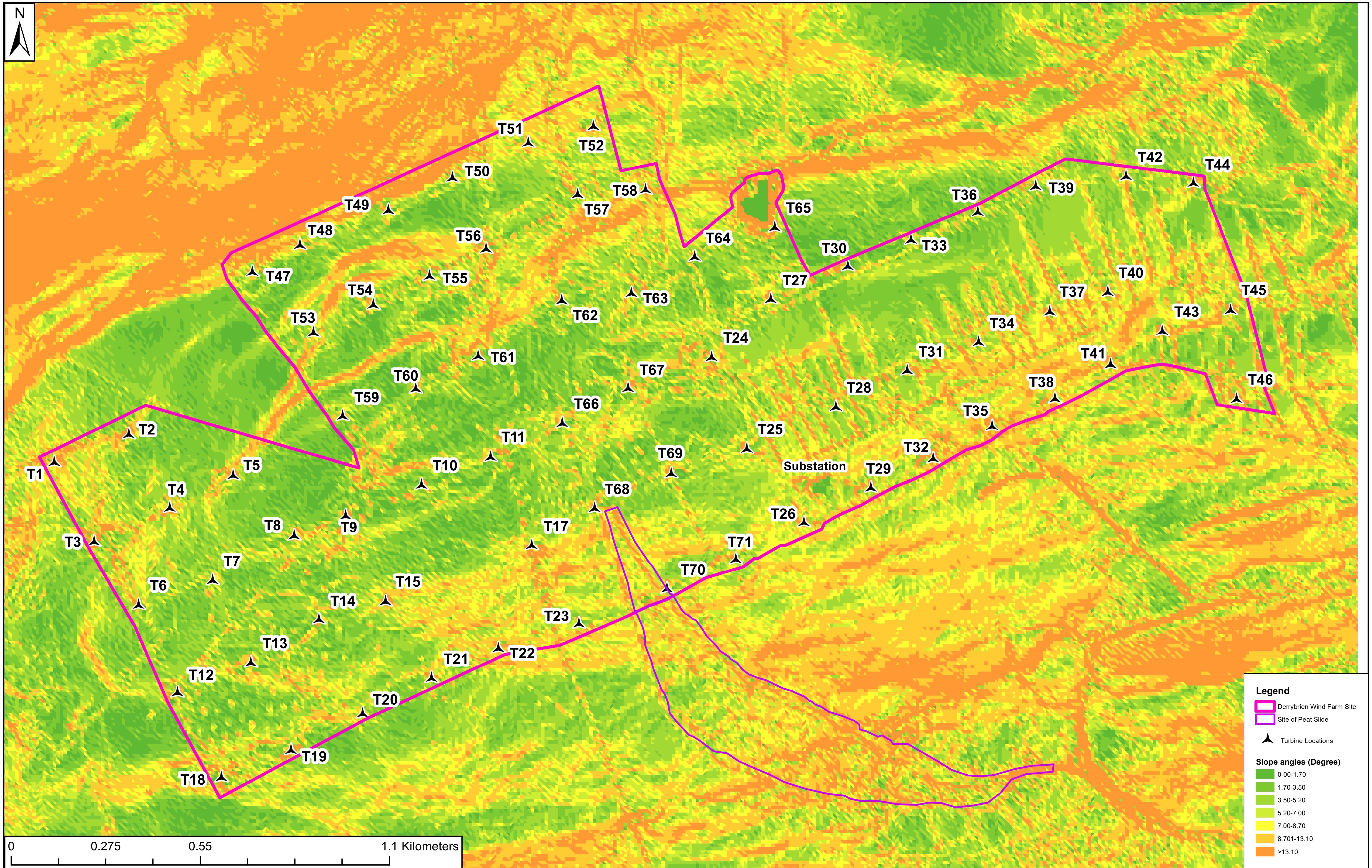


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PRODUCTION UNIT: Civil & Environmental Engineering

DRAWING TITLE:

**Appendix 11A - Figure 2 - Ground surface slope angles based on post-construction LIDAR survey**



| DRAWN | PRODUCED | VERIFIED | APPROVED | APPROVAL DATE |
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**Plate 1 Typical site land at Derrybrien Wind Farm**

**Plate 2 Drainage channel at Derrybrien**

gaining elevation again as it passes Lough Agannygal, at about 195 mOD. The route ends at the Agannygal Substation, which is located to the south east of Cashlaundrumlahan Mountain and north of Lough Atorick, at an elevation of approximately 190 mOD.

The peat slide which occurred during Project construction originated within the wind farm site close to the southern boundary and extended mainly onto Coillte land and some onto private land between the wind farm and Black Road Bridge.

Measures undertaken in response to the peat slide included the rebuilding of short sections of floating road within the wind farm site at two locations in the vicinity of T68 and T70 which also acted as containment barrages and the installation of eight barrages (four boulder and four earthen) along and downslope of the route of the slide between the wind farm and downstream of Flaggy Bridge of which four still remain in-situ in 2020. Of the eight barrages, two (Barrages 1 and 2) are located upstream of Black Road Bridge and act as Coillte access tracks, two (Barrages 3 and 4) are within the basin of a small stream tributary of the Owendalulleegh River and four are no longer in place. Accumulated peat from two of the barrage locations (Barrages 2 and 3) and from land adjacent to Black Road Bridge which resulted from the slide was placed in repositories on adjacent lands upstream of Flaggy Bridge.

## Scope

This assessment considers the following:

I. The Department of Environment, Heritage and Local Government guideline document to Planning Authorities in relation to Flood Risk Management (November 2009);
II. Future changes including climate and catchment characteristics;
III. Review of data on recorded historic floods;
IV. Risk of flooding to the Project Areas from flood flow from neighbouring watercourses and direct rainfall causing pluvial flooding;
V. Risk of flooding from groundwater;
VI. The impact of surface water runoff from the Project Areas on the flow regimes in downstream watercourses;
VII. Loss of floodplain.

# I. Planning Guidelines

In November 2009 the Department of Environment, Heritage and Local Government issued "The Planning System and Flood Risk Management Guidelines for Planning Authorities".

These Guidelines set out the policy on development and flood risk in Ireland and provide a framework for the integration of flood risk assessment into the planning process. The objective is to ensure that flood risk is taken into account at all stages in the planning process and as a result to:

- Avoid inappropriate development in areas at risk of flooding,
- Avoid new developments increasing flood risk elsewhere,
- Ensure effective management of residual risks for development permitted in floodplains.

The Guidelines set out a staged approach for the consideration of flood risk in relation to developments as follows: -

"*Stage 1: Flood risk identification – to identify whether there may be any flooding or surface water management issues related to either the area of regional planning guidelines, development plans and LAP's or a proposed development site that may warrant further investigation at the appropriate lower level plan or planning application levels;*"

"*Stage 2: Initial flood risk assessment – to confirm sources of flooding that may affect a plan area or proposed development site, to appraise the adequacy of existing information and to scope the extent of the risk of flooding which may involve preparing indicative flood zone maps. Where hydraulic models exist the potential impact of a development on flooding elsewhere and of the scope of possible mitigation measures can be assessed. In addition, the requirements of the detailed assessment should be scoped;*" and

"*Stage 3: Detailed flood risk assessment – to assess flood risk issues in sufficient detail and to provide a quantitative appraisal of potential flood risk to a proposed or existing development or land to be zoned, of its potential impact on flood risk elsewhere and of the effectiveness of any proposed mitigation measures.*"

The Guidelines classify developments into three vulnerability classes based on the effects of flooding

i) Highly vulnerable development,

ii) Less vulnerable development and

iii) Water Compatible development.

Essential infrastructure such as electricity substations and wind turbines are classed as highly vulnerable developments.

The Guidelines classify land areas within three flood zones based on the probability of flooding. Flood zones are defined as follows in the Guidelines:

- Zone A is at high risk. In any one year, Zone A has a 1 in 100 year (1%) chance of flooding from rivers and a 1 in 200 year (0.5%) chance of flooding from the sea.
- Zone B is at moderate risk. The outer limit of Zone B is defined by the 1 in 1,000 year (or 0.1%) flood from rivers and the sea.
- Zone C is at low risk. In any one year, Zone C has less than 1 in 1,000 year (<0.1%) chance of flooding from rivers, estuaries or the sea.

In the identification of flood zones, no account should be taken of any flood defences present (i.e. flood relief walls or embankments), as though such flood defences did not exist.

| Development Classification | Flood Zone A (High Probability of Flooding) | Flood Zone B (Moderate Probability of Flooding) | Flood Zone C (Low Probability of Flooding) |
|---|---|---|---|
| **Highly Vulnerable Development (including essential infrastructure)** | Justification Test | Justification Test | Appropriate |
| **Less Vulnerable Development** | Justification Test | Appropriate | Appropriate |
| **Water-Compatible Development** | Appropriate | Appropriate | Appropriate |

**Table 1 Matrix of vulnerability versus flood zone to illustrate appropriate development and that required to meet the Justification Test (reproduced from Planning Guidelines)**

Table 1, which is reproduced from the guideline document to Planning Authorities in relation to Flood Risk Management states that essential infrastructure, including electricity substations and electricity generating wind turbines should be located within the low flood risk zone - Flood Zone C (as highlighted above).

Table 1 refers to the use of a Justification Test under certain circumstances. In cases where there are insufficient sites available to locate a development in the appropriate low flood risk zone, the guideline documents allows for consideration of sites within flood risk zones. A Justification Test is then required to assess such proposals in the light of proper planning and sustainable development objectives.

This flood risk assessment considers the flood risk of the proposed development in relation to all three stages of the staged approach outlined above.

# II. Climate Change

The Planning System and Flood Risk Management Guidelines for Planning Authorities recommend that climate change be factored into consideration for flood risk assessments although there is no national guideline on how to account for the additional risk. The Guidelines instead recommend a precautionary approach to climate change effects in respect to flooding due to the high level of uncertainty in predicting its effects.

The Fluvial Flood Zone extents arising from the Catchment Flood Risk Assessment Management Studies (CFRAMS) mapping represent the current status in relation to flood risk with no account taken of climate change. However, an additional interactive flood map layer is available on www.floodinfo.ie to show the extent accounting for the different future scenarios. There is a high degree of uncertainty in relation to the potential effects of climate change, and therefore a precautionary approach is required. Examples of a precautionary approach include:

- Recognising that significant changes in the flood extent may result from an increase in rainfall or tide level and accordingly adopting a cautious approach to zoning lands in these potential transitional areas.
- Ensuring that the finish levels of structures are sufficiently elevated to cope with the effects of climate change over the life time of the development.
- Ensuring that structures to protect against flooding (e.g. defence walls) are capable of adaptation to the effects of climate change when there is more certainty about the effects (e.g. foundations of flood defence designed to allow future raising of flood wall to combat climate change).

## Guidance for UK

Climate change scenarios for the UK suggest fluvial floods in the 2080s increasing by up to 10% (low and medium low scenarios) or by up to 20% (medium high and high scenarios). Present recommendations are to include in the design flow a 20% increase in flood peaks over 50 years return period as a result of climate change. This scenario, if based on the Irish growth curve would result in a present day 100-year flood becoming a 25-year flood in approximately 50-years. The extent and expected depths of flooding are derived based on these flows.

Other predicted climate change effects for the UK are:

- A 4 – 5 mm per annum rise in mean sea level;
- Additional intensity of rainfall of 20% to 30%;
- An additional 30% winter rainfall by the 2080s;
- A reduction of 35% - 45% rainfall in summer;
- The magnitude of the 1 in 100-year storm event to increase by 25%.

**In the UK research is ongoing to assess regional variations in flood allowances and the rate of future change. Current research thus far does not provide any evidence for the rate of future change let alone consider regional variations in such a rate. The UK Department of Environment, Food and Rural Affairs (DEFRA) Flood and Coastal Defence Appraisal Guidance (DEFRA, 2008) gives ranges of climate change factors as per Table 2Table 2 DEFRA-recommended climate change factors**

and as a pragmatic approach it is suggested that 10% should be applied up to 2025, rising to 20% beyond 2025.

| Parameter | 1990 - 2025 | 2025 - 2055 | 2055 - 2085 | 2085 - 2115 |
|---|---|---|---|---|
| Peak rainfall intensity (preferably for small catchments) | +5% | +10% | +20% | +30% |
| Peak river flow (preferably for larger catchments) | +10% | +20% | | |

**Table 2 DEFRA-recommended climate change factors**

## Guidance for Ireland

In Ireland, general practice is to use a medium-range climate change allowance of +20% for flood flows over the next 100 years. This rate has been adopted by the OPW for all of its CFRAM Studies.

Research into climate change in Ireland is coordinated by Met Éireann through Community Climate Change Consortium for Ireland (www.c4i.ie). The OPW has recommended allowances of +20% on fluvial flows for climate change as recommended in the draft guidelines entitled "Climate Change Sectoral Adaptation Plan, Flood Risk Management" (OPW, 2015) for mid-range future scenario (MRFS) and +30% for the high-end future scenario (HEFS).

Notwithstanding the precautionary principle, the flood risk zones defined in the 'The Planning System and Flood Risk Management Guidelines for Planning Authorities' are based on the present-day assessment of the 100-year (1% Annual Exceedance Probability (AEP)) and 1000-year (0.1% AEP) return period for fluvial flooding and the 200-year (0.5% AEP) and 1000-year return period for tidal flooding. The OPW provides specific guidance as to the allowances in its publication entitled "Climate Change Sectoral Adaptation Plan" and these allowances are summarised in Table 3.

| Parameter | Mid-Range Future Scenario MRFS | High-End Future Scenario HEFS |
|---|---|---|
| Mean Sea Level Rise | +500 mm | +1000 mm |
| Land Movement | -0.5 mm/year | -0.5 mm/year |
| Extreme Rainfall Depths | +20% | +30% |
| Flood Flows | +20% | +30% |

**Table 3 OPW-recommended Climate Change Allowances in Flood Parameters for Future Scenarios**

## III. Historic Floods

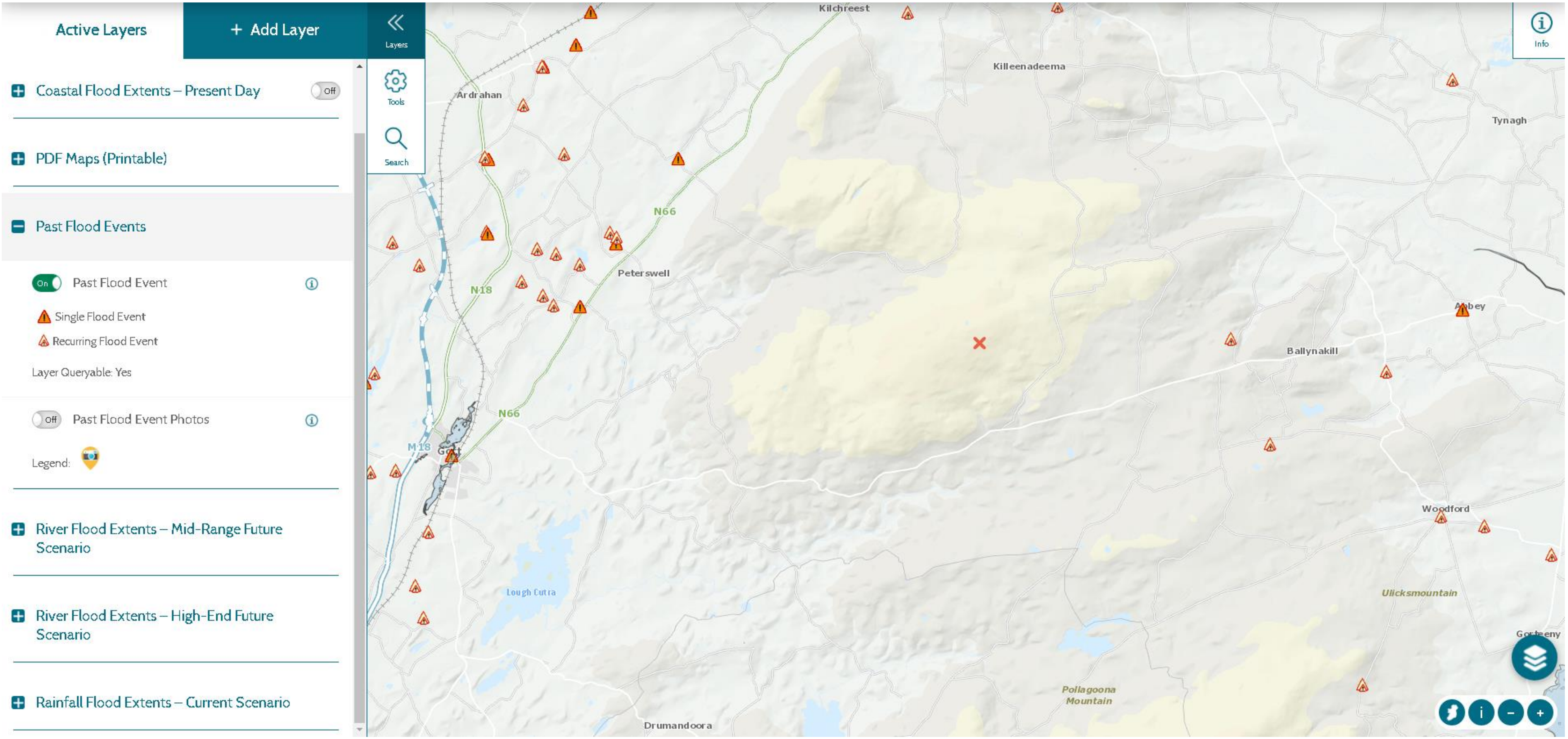
A desk review of historic flooding was undertaken primarily using OPW website floodinfo.ie. The ‘Past Flood Events’ layer forms a record of all available flood records held by the OPW, all local authorities and other relevant state organisations such as the EPA and the Department of Communications, Climate Action and Environment. There are no mapped reports of recurring flooding within the site and there is no significant risk of flooding due to the elevated nature of the majority of the Project area relative to the surrounding area (Figure 4). The nearest area downstream affected by extensive flooding in the catchment which drains the north side of the wind farm site is 15 km downstream at Ballylee on the Streamstown River. The nearest area downstream affected by extensive flooding in the catchment draining the south side of the wind farm is over 20 km downstream close to Gort. The history of flooding in the Gort Lowlands area is discussed in detail in Appendix B.

There is no “liable to flood lands” or flood symbols on the historical 6” or 25” mapping for the Project areas that identifies areas that are “prone to flooding” within or downstream of the site. There are also no areas within the site or immediately downstream of it mapped as “Benefiting Lands” and are indicative of areas of land identified as subject to flooding or poor drainage which have been the subject of an OPW drainage scheme. The nearest such drainage district to the Project study area is the Annagh downstream of Peterswell in the Boleyneendorrish catchment.

The wind farm site has been managed for almost 20 years and there is no record of any serious flooding on or in the vicinity of the Project areas in that time despite a number of large flood events affecting the surrounding region. Gort Town was and is affected by flooding with an OPW Flood Relief Scheme successfully implemented for the Main Street bridge area in 1997. However, the areas downstream of Gort have experienced inundation during prolonged winter floods. Lough Cutra is gauged by the OPW and the lake level generally rises and falls by 1.2 m over the course of a year between the driest and wettest periods.

**PLACEHOLDER**

**Figure 4 Historic Flood Mapping (floodinfo.ie); wind farm site marked by red X**



Active Layers
+ Add Layer
Layers
Tools
Search
Info
Coastal Flood Extents – Present Day
Off
PDF Maps (Printable)
Past Flood Events
On
Past Flood Event
Single Flood Event
Recurring Flood Event
Layer Queryable: Yes
Off
Past Flood Event Photos
Legend:
River Flood Extents – Mid-Range Future Scenario
River Flood Extents – High-End Future Scenario
Rainfall Flood Extents – Current Scenario
Kilchreest
Killeenadeema
Ardrahan
Tynagh
N66
N18
Peterswell
Ballynakill
M18
Lough Cutra
Woodford
Ulicksmountain
Pollagoona Mountain
Drumandoora

# IV. Flooding Risk to Project Area

## CFRAMS and PFRA Mapping

As part of Ireland's obligations under the EU "Floods" Directive (Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks), the OPW is currently engaged in the generation of new mapping which will provide predictive estimates of the extent of floodplains as part of its CFRAM Studies. This programme is being undertaken on a River Basin District basis. The Derrybrien Wind Farm Project site is primarily located within the Western River Basin District with a very small section of the site within the Shannon District. The Western CFRAMS programme was carried out between 2011 and 2016. Finalised flood maps were released through floodinfo.ie in April 2018. The OPW CFRAMS river flood maps and CFRAMS Preliminary Flood Risk Assessment (PFRA) maps were consulted to identify those areas at risk of flooding.

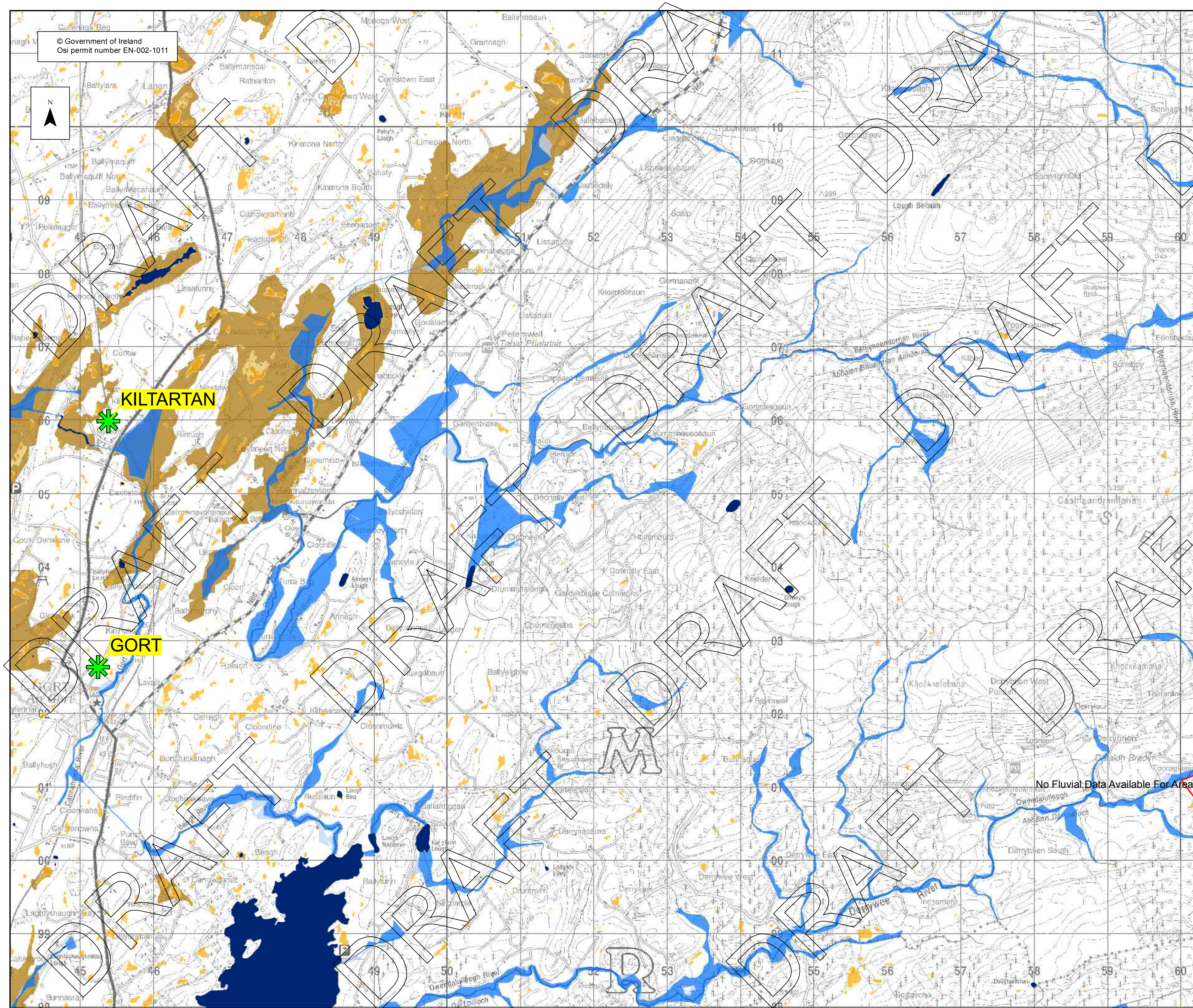
The PFRA mapping shows the extents of the indicative 100-year flood zone which relates to fluvial and pluvial (river and rainfall) flood events (Figure 5 and Figure 6). There is no 100-year fluvial flood zone mapped within the Project area, which includes the overhead line (OHL) route and Agannygal substation. Where it is mapped in close proximity to the development, it typically exists in close proximity to the main Owendalulleegh River channel or its contributing second or third order streams. No pluvial flood zones are mapped within the site, as would be expected in mountainous rural terrain with sloping topography. CFRAMS interactive flood mapping (www.floodinfo.ie) following on from the PFRA maps, does not identify and analyse areas at risk of flooding close to the wind farm site as it was not considered by the OPW as an Area for Further Assessment (AFA) as part of the CFRAMS programme.

As discussed, the OPW recommends that a medium range climate change factor of up to 20% be considered for river flows and 30% for rainfall. Given that the wind farm site is towards the top of the watershed this increase will not alter the low flood risk zone designation for the Derrybrien wind farm site. Interactive mapping on the floodinfo website does illustrates the extent of AFAs within the 1-in-1000 year fluvial flood zone under the MRFS (Figure 7).

During the post-construction phase of the wind farm, the drainage network has experienced a variety of large storm events. These have ranged from intense short-duration events in which approximately 60 mm of rain fell in 24 hours (as measured at Gort Derrybrien II Met Station) (7th June 2012, Storm Desmond on 5th December 2015) to long-duration winter floods which saturated the wider area (November 2009, December 2015 to January 2016).

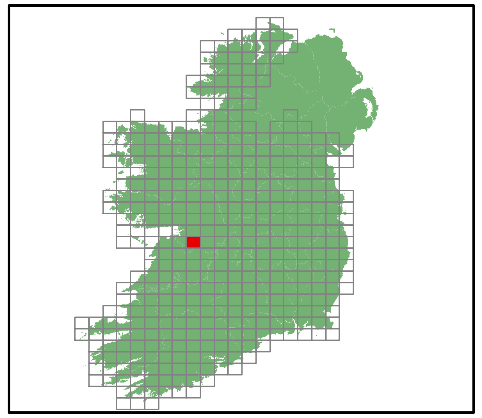
The drainage network on the wind farm has to date demonstrated sufficient capacity to convey floodwaters without excessive flooding of access tracks and turbine bases or erosion of drainage channels. Similarly, the drainage networks associated with both substations have no record of flooding issues since commissioning (14 years). It is reasonable to conclude that the wind farm site, OHL route and Agannygal substation site, being on elevated upland sites, with the exception of a small area on the OHL line, are located in Flood Zone C and are therefore at low risk of flooding as defined by the Planning Guidelines.

Notwithstanding the low fluvial and pluvial flood risk, the raised bog acts as a saturated sponge and retains the water table at or close to ground level in undrained areas.




0.5 0.25 0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 Kilometers

## Location Plan :



## Legend:

### Flood Extents

- Fluvial - Indicative 1% AEP (100-yr) Event
- Fluvial - Extreme Event
- Coastal - Indicative 0.5% AEP (200-yr) Event
- Coastal - Extreme Event
- Pluvial - Indicative 1% AEP (100-yr) Event
- Pluvial - Extreme Event
- Groundwater Flood Extents
- Lakes / Turloughs

### PFRA Outcomes

- Probable Area for Further Assesment
- Possible Area for Further Assesment

Important User Note:

The flood extents shown on these maps are based on broad-scale simple analysis and may not be accurate for a specific location. Information on the purpose, development and limitations of these maps is available in the relevant reports (see www.cfram.ie). Users should seek professional advice if they intend to rely on the maps in any way.

If you believe that the maps are inaccurate in some way please forward full details by contacting the OPW (refer to PFRA Information leaflets or 'Have Your Say' on www.cfram.ie).

Office of Public Works
Jonathon Swift Street
Trim
Co Meath
Ireland

Project :
PRELIMINARY FLOOD RISK ASSESMENT (PFRA)

Map :
PFRA Indicative extents and outcomes
- Draft for Consultation

| | |
|---|---|
| Figure By : PJW | Date : July2011 |
| Checked By : MA | Date : July 2011 |
| Figure No. : 2019 / MAP / 194 / A | Revision 0 |
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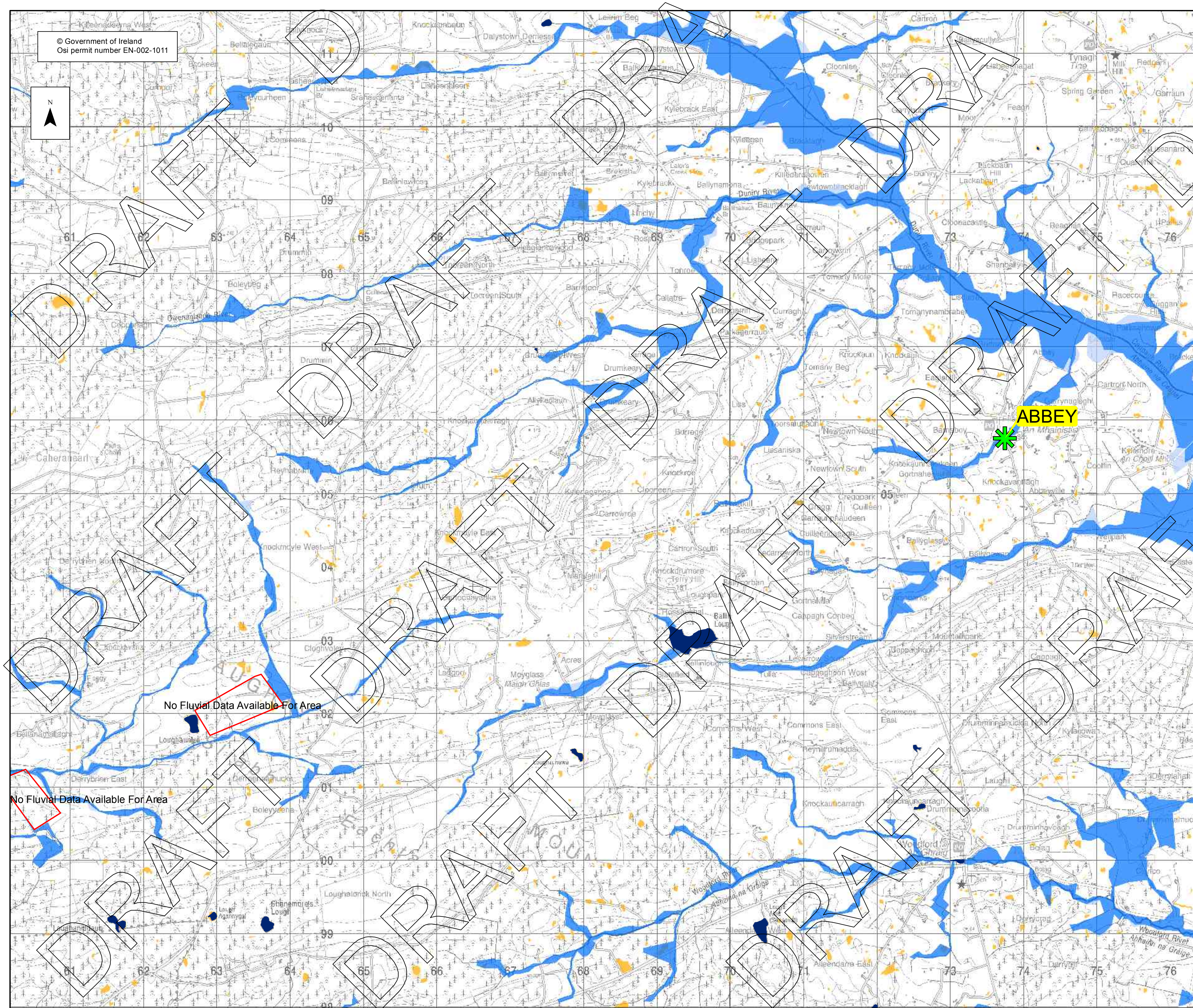
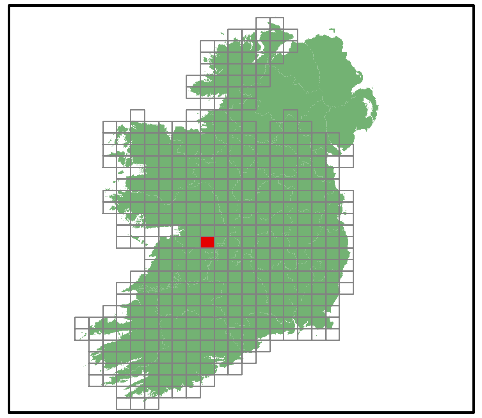



0.5 0.25 0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 Kilometers

## Location Plan :



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Project :
PRELIMINARY FLOOD RISK ASSESMENT (PFRA)

Map :
PFRA Indicative extents and outcomes
- Draft for Consultation

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| Figure By : PJW | | Date : July2011 | |
| Checked By : MA | | Date : July 2011 | |
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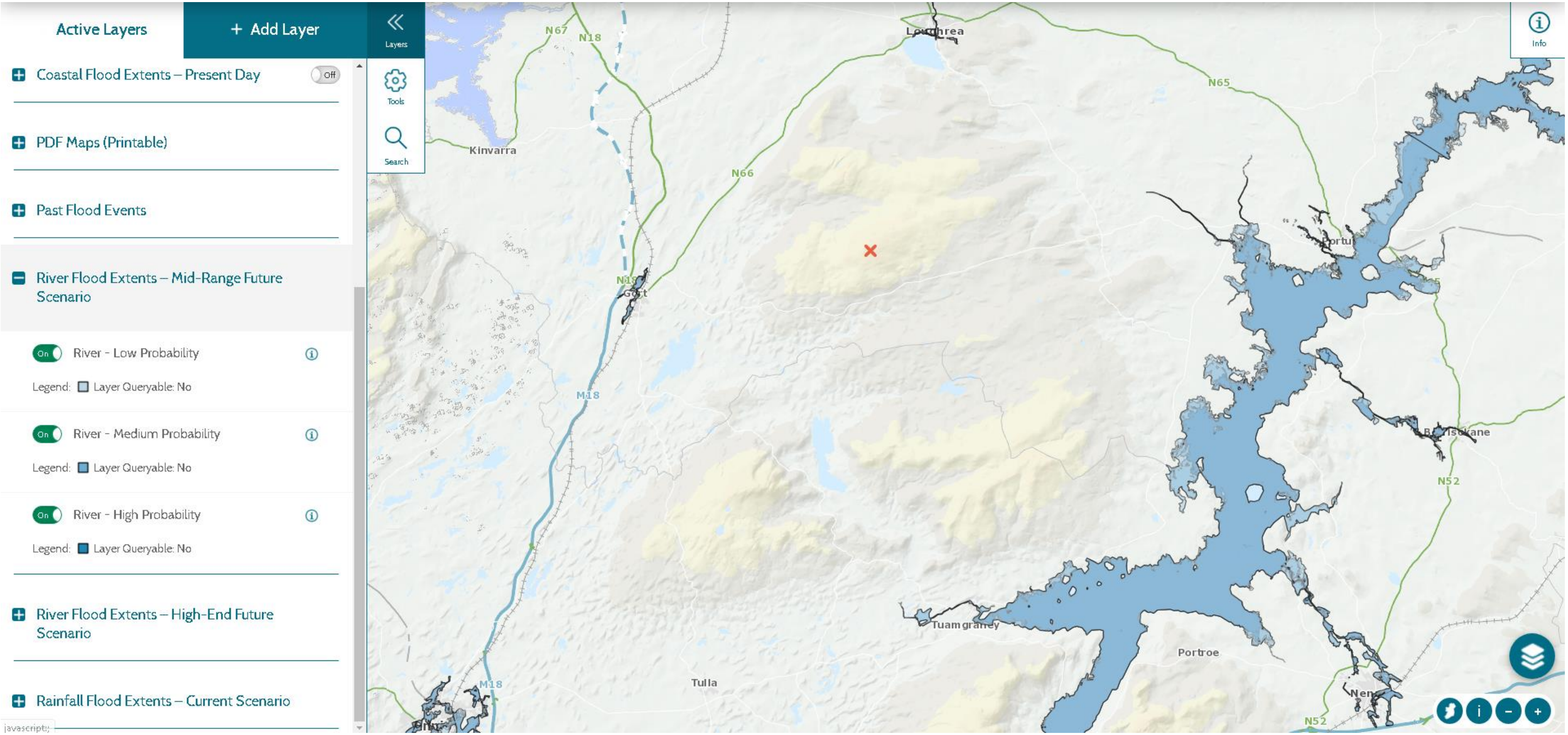
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+ Add Layer
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Search
Info
Coastal Flood Extents – Present Day
Off
PDF Maps (Printable)
Past Flood Events
River Flood Extents – Mid-Range Future Scenario
On
River - Low Probability
Legend: Layer Queryable: No
On
River - Medium Probability
Legend: Layer Queryable: No
On
River - High Probability
Legend: Layer Queryable: No
River Flood Extents – High-End Future Scenario
Rainfall Flood Extents – Current Scenario
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N66
N52
M18
Kinvarra
Tuamgraney
Portroe
Tulla

## Wind Farm

**Baseline Environment**

The pre-existing drainage system on the wind farm site (Figure 8) moved water by gravity following the natural gradient of the site, utilising a network of longitudinal drains and stream channels to discharge surface drainage waters off site to the local river systems. These were c. 27 km of drainage channels in the form of ditches dug prior to the wind farm project and ran parallel to existing floating access roads on one or both sides of the track to avoid problems of localised ponding affecting turbary and forestry access. These drains discharged to perpendicular drains which discharged surface water away from the mountain. Drainage channels on the eastern side of the site were maintained by turbary land owners prior to the wind farm Project and on the remainder of the site by Coillte.

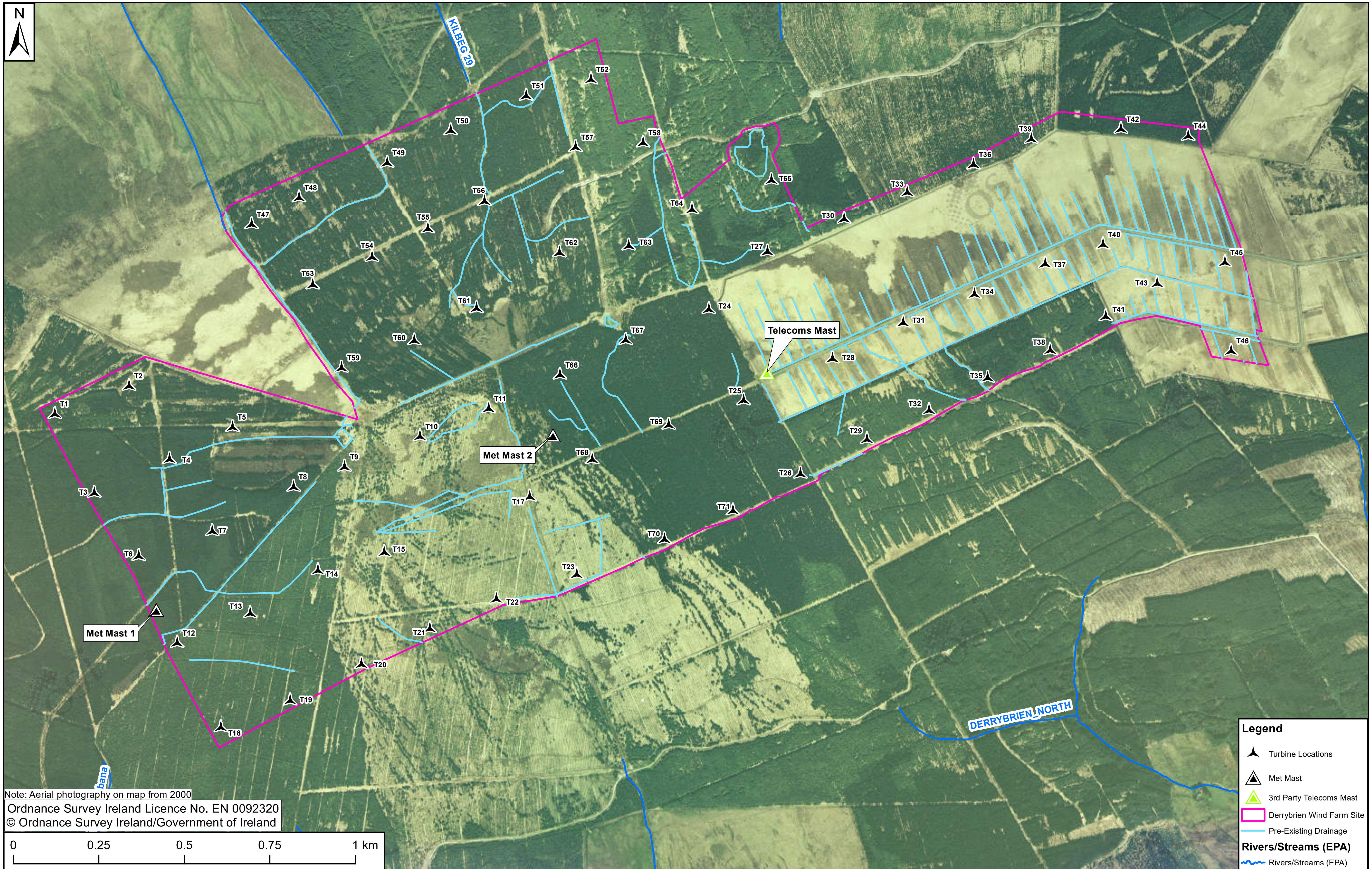
All of the drains (both pre-existing and constructed) and watercourses are narrow open channels, typically 1-2 m deep, with culverts under the site access tracks. Where the peat is shallow the drains penetrate into the underlying glacial till. However, in peat greater than 1-2 m deep the drains are only excavated into the peat. At the east end of the site the drainage network reflects the outline of the turbary plots on that side of the site. Slope angles in the drainage network vary from 2 to 5 degrees (i.e. gradients of 1:10 to 1:30) in this area, with the steepest channels draining toward the southeast.

Blanket bogs such as that on which Derrybrien Wind Farm is sited are wetlands that are fed directly by rainfall to give rise to their characteristic saturated and water logging surface conditions. The living surface peat layer (0.1 – 0.3 m thick), the acrotelm, can have a moisture content of 90 – 98% and features the peat-forming vegetation, i.e. sphagnum moss, cotton grass and other materials including purple moor grass, heather stems and roots. The acrotelm supplies plant material which then slowly forms peat in the underlying catotelm layer. Typically, active peat bogs grow slowly at 0.5 – 1.0 mm per annum.  In active bogs sphagnum mosses form a protective carpet which is a mosaic of sphagnum species growing as dense hummocks, low growing lawns and as hollows that create the characteristically undulating bog surface. In these undrained conditions the saturated bog promotes increased surface ponding as pools and mires, also generating overland runoff as sheet flow across the surface of the bog. Active blanket bog generally remains close to saturation throughout the year and therefore has limited available storage except in depressions where larger pools can form before spilling overland.

In the case of the Derrybrien Wind Farm site, the former land use was primarily i) turbary and ii) commercial forestry, which both represent a drained bog situation.

**i) Turbary Bog**

In a damaged or degraded bog, the acrotelm has been lost because of drainage, burning, trampling / grazing, afforestation or agriculture (which includes fertiliser application as well as drainage). The degradation exposes the unprotected underlying catotelm layer to atmospheric conditions including surface water runoff. Subsequently, non-wetland vegetation becomes established, accelerating the aeration, drying and shrinkage process (primary consolidation). The loss of moisture and thus buoyancy in the upper layers further squeezes water from the catotelm layer (secondary compression).

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DRAWING TITLE: Appendix 11A - Figure 8 - Drainage layout prior to construction (circa 2000)



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Drainage of peat bogs is generally focused on lowering the water table through a network of deep connecting drains often for domestic and commercial peat production, for forestry production or for agricultural grassland reclamation to provide an unsaturated soil root zone that enables plant growth to succeed. The construction of drainage ditches in a bog provides shorter pathways for surface water to run off and, depending on the density of the drainage network, will ultimately reduce water logging and over time dry out the surface acrotelm layer and more gradually the upper layers of the catotelm. The acrotelm layer offers relatively low resistance to vertical and lateral water movement and, consequently, drainage tends to empty water reasonably readily from the acrotelm layer. However, given this layer is relatively thin, the drainage effects on the surrounding water table are minor. The drying process will over time alter the surface topography and increase the range in the water table between summer and winter levels.

**ii) Commercial Forestry**

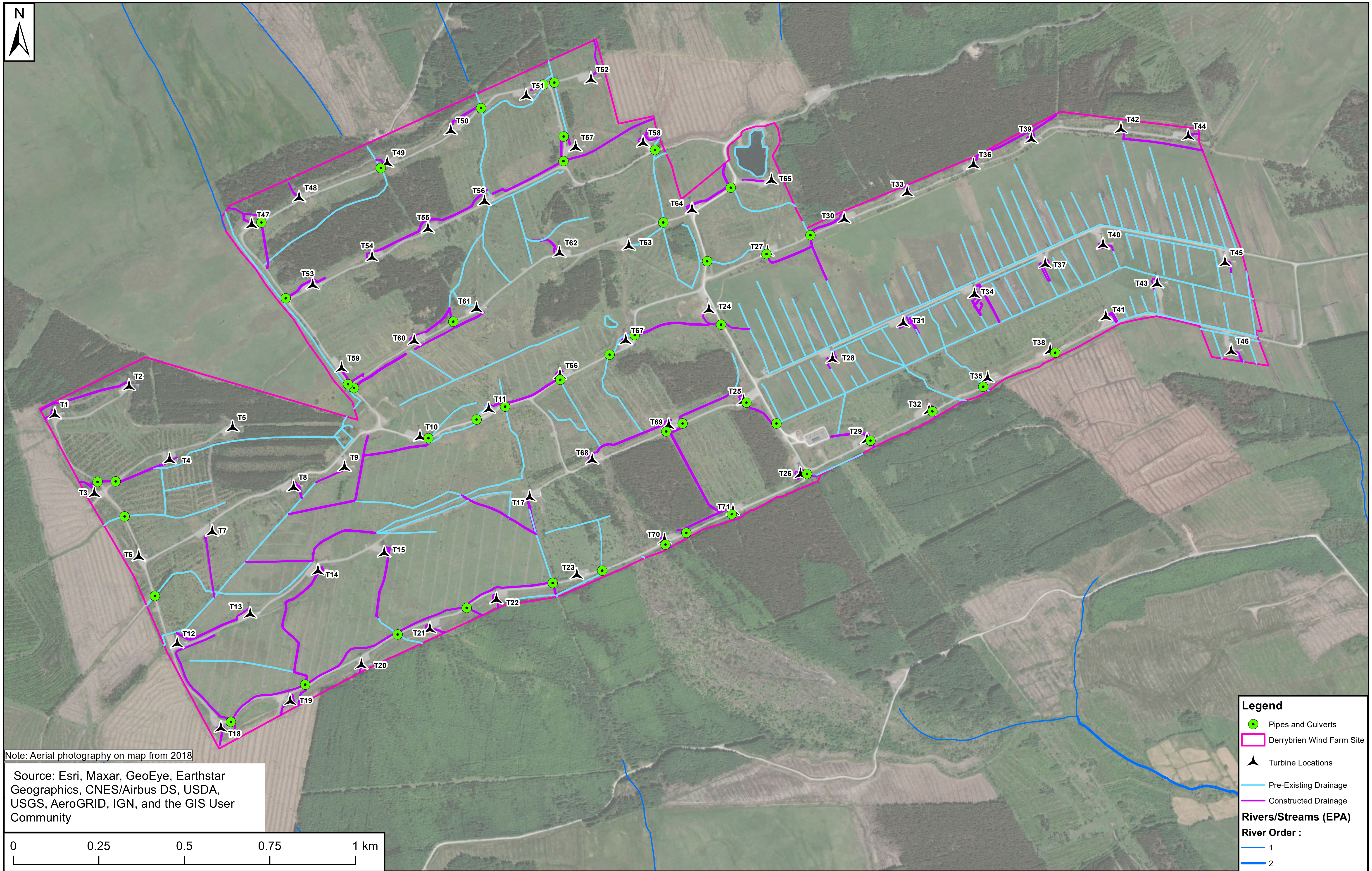
Forestry plantations such as that which occupied the majority of the wind farm site prior to 2003 cannot tolerate permanently waterlogged conditions such as the saturated conditions found in blanket bogs. For forestry to flourish it is necessary to drain the peat and remove excess surface water to locally lower the perched water table level. It is also necessary to plough the surface to provide a slightly raised ridge that acts as a micro-habitat for tree seedlings to establish with the ploughed furrow conveying the drainage away from the planted ridge. Tree planting takes place in rows parallel to the ploughed furrow with the areas in between the ridges often an efficient avenue for runoff to migrate downgradient to receiving watercourses. As such, the overall effect of forestry plantations like this is to increase peak winter flood runoff rates from upland areas. It should be noted however that this only applies when antecedent conditions are wet such as during winter. In drier conditions, the soil moisture deficit may be greater where the root zone promotes drying of the underlying peat, thus effectively providing a degree of attenuation.

Given the upland nature and gradients of the area, the site on which the wind farm was developed represented high runoff category lands.

**Impact of Wind Farm Project on Flood Regime**

Approximately 12 km of road drainage and turbine foundation drainage was constructed for the wind farm Project, most of which connect the turbine foundation drainage to the pre-existing drains on site. Figure 9 shows the network of open drains on the site, both existing former drainage (cyan) and constructed collector drainage (magenta). The vast majority of the circa 27 km of pre-existing channels were left unchanged during construction except where there was a conflict with new infrastructure. In areas where there were high concentrations of flow upstream of access tracks and / or close to turbine foundations, sections of drainage were re-aligned or deepened to reduce any risk of localised surface ponding and saturate conditions that could give rise to buoyancy issues in respect to the turbine structure. Some minor cleaning out and maintenance work took place as required.

Regular maintenance has been carried out as necessary since commissioning of the site. Drainage inspections are carried out monthly and following heavy rainfall or snow events. In

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**Appendix 11A -Figure 9 - Wind Farm Pre-existing & Constructed Drainage**



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DRAWING NUMBER: **QS-000280-01-D460-012-019-000** addition to this, annual geotechnical inspections have identified drainage maintenance issues which generally involve localised clearing out and maintaining sections of site drains.

The use of floating roads, which accounts for 18.8 km out of 19.7 km of on-site access tracks (both pre-existing and constructed), facilitates rainwater infiltration into the peat layer beneath and as such does not require additional road side drainage with rainwater falling onto the road allowed to spill over the edge into the undisturbed peat. Floating roads are sympathetic to the natural drainage as they act neither as a barrier nor as a deep wide permeable drain that would dewater the adjacent saturated peat into its formation layer and convey elsewhere with the gradient of the road. It should be noted that all of the 2.24 km of tracks on the site prior to construction were floating roads. These allowed surface water to pass without issues or need for diversions. It is therefore with confidence that one can comment on the effect of floating roads on drainage at this wind farm site. The remaining 0.9 km of road which was non-floating were in small sections around Borrow Pit / Quarry 3 in the north-east corner of the site and at turbines T68 and T70 which were rebuilt with rockfill embankments following the peat slide in October 2003.

During storm events, runoff from hardstanding areas has been conveyed through the nearest drains to outlets from the site. These drains have been and continue to be inspected and maintained on a regular basis to form a more efficient route to the outlet point of the wind farm site before meeting with rivers downstream.

Culverts have been inserted at various wind farm access road crossings as necessary to maintain the conveyance path of the existing drains crossed and thus prevent excessive ponding of water on the uphill sides of these roads. The culverts installed are necessary to maintain the drainage runs and avoid unnecessary diversions of drainage on the site.

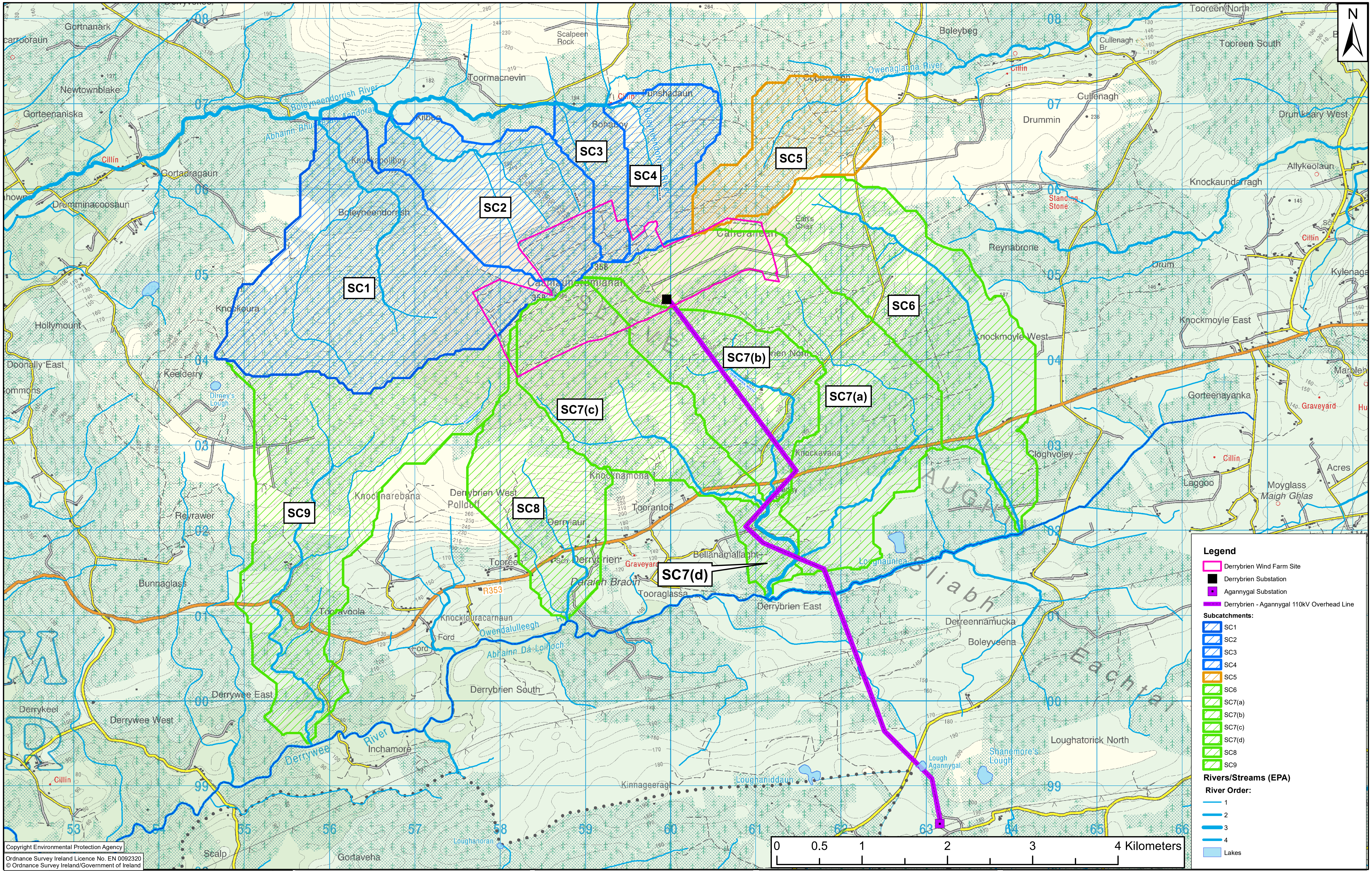
It should be noted that the extent of constructed wind farm drainage is, in comparison to similar developments of this type and scale, minor relative to the overall existing drainage.

The wind farm site lies on relatively gently sloping ground surrounding the Peak of Cashlaundrumlahan Mountain and is composed of the headwaters of several small subcatchments which drain from this summit to downstream rivers to the north and south of the wind farm site (see Figure 10). As such there are no external surface water inflows and only the direct rainwater falling on the site contributes to increases in flows and water levels. The site is ungauged in respect of flood flow estimation and requires ungauged flood estimation methods to determine the Greenfield runoff rate and the return period design flows.

**Assessment of flood regime on-site**

Extreme value analysis (EVA) is a statistical method that can be used to estimate the probability and severity of events that are more extreme than any that exist in a given data series. EVA may be used to estimate the probability and severity of future events based on a limited set of data. It is important to remember that the uncertainty in the projected extreme events increases as the return period exceeds the length of the data series. Many probability distributions, such as General Extreme Value (GEV), Gumbel and Log-Pearson, have been developed to model extreme rainfall processes but there is no general agreement as to which is the most suitable distribution for accurate extreme rainfall estimates.

The Flood Studies Update (FSU) Depth Duration Frequency (DDF) model developed by Met

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DRAWING TITLE: Appendix 11A - Figure 10 - Subcatchments draining from wind farm site to major rivers



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Éireann (Fitzgerald, 2007) consists of an index (median) rainfall and a log-logistic growth curve. Growth curve parameters were determined at each rainfall station using the DDF model and these were interpolated and mapped on a 2 km nationwide grid. The growth curve provides a multiplier of the median rainfall for any required return period. The DDF table generated for the Derrybrien Wind Farm site is shown in Table 4. No allowance is made for the effects of climate change on the rainfall regime. The OPW recommend a climate change factor of 20% to be added to the rainfall depth for extreme events under the MRFS (Table 3).

The time of concentration ($t_c$) (i.e. time taken for water to flow from the furthest extents of the catchment to the outlet point) is a useful indicator of how different catchments react to storm events. The duration of the time of concentration can be interpreted as the time between the peak rainfall and the peak of flow at the outlet from a given catchment. It can be estimated using a variety of empirical equations one of which is the Bransby Williams formula (Bransby Williams, 1922) which is widely used and recommended where there is no specific formula available for a particular region (French et al, 1974) –

$$t_c = \frac{58L}{A^{0.1}S^{0.2}}$$

where L is the main stream length measured to the catchment divide (km);

S is the equal area slope of the main stream projected to the catchment divide (m/km);

A is the catchment area ($km^2$).

The most significant upstream area associated with any one of the many channels distributed across the site is the pre-existing turbary drain on the north side of the access road draining past turbine T35 in the south-east of the site. This has an area of 0.36 $km^2$ and a $t_c$ of just under 1 hour.

**100-year rainfall event**

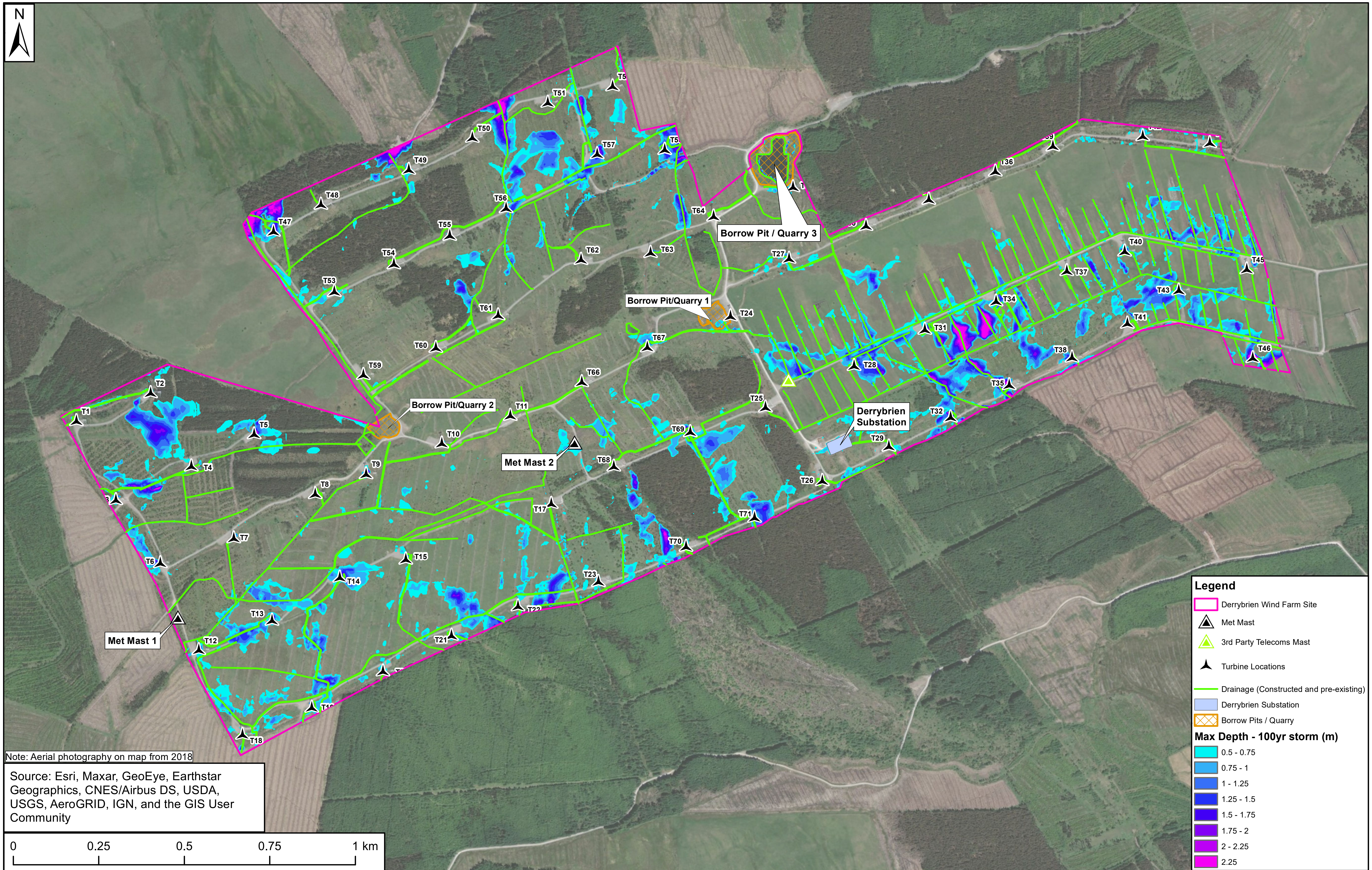
According to the FSU Rainfall Depth Duration Frequency (DDF) model, the 100 year return period rainfall depth for a 1 hour event for Derrybrien Wind Farm is 35.9 mm. By including allowance for the climate change factor, this increases the 100-year rainfall depth to 43 mm.

LIDAR data taken across the wind farm site in 2012 at 1 m x 1 m resolution was used to build a representative digital elevation model (DEM) of the wind farm. Simulation of the indicative 100-year flood levels using the HEC-RAS River Analysis System for the critical flood period (1 hour) generally shows the greatest depths of water draining to within and to the vicinity of drainage channels (Figure 11). The two-dimensional (2D) model has 1 $m^2$ resolution and simply relies on the inputted DEM, rainfall hydrograph and Manning's roughness coefficients for the 2D flow area to compute indicative rainwater depths and their change for a prescribed time step and simulation duration.

Given the inherent limitations associated with a LIDAR survey, the DEM cannot account for pipes and culverts which pass underneath access tracks and so, the greatest depths modelled are at the most significant pipe crossings, the largest of which is just downstream of T35. However, for the purposes of assessing where the greatest onsite flood risk arises, the assumption that culvert pipes could be blocked in the first flush of an extreme rainfall event is a conservative one to draw attention to areas that could be vulnerable in such an event.

| | **FREQUENCY (i.e. Return Period) (years)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DURATION | **0.5** | **1** | **2** | **3** | **4** | **5** | **10** | **20** | **30** | **50** | **75** | **100** | **150** | **200** | **250** |
| **5 mins** | 2.8 | 3.9 | 4.5 | 5.4 | 6 | 6.4 | 7.9 | 9.6 | 10.7 | 12.3 | 13.7 | 14.7 | 16.3 | 17.6 | 18.7 |
| **10 mins** | 3.9 | 5.5 | 6.3 | 7.5 | 8.3 | 9 | 11.1 | 13.4 | 15 | 17.1 | 19 | 20.5 | 22.8 | 24.5 | 26 |
| **15 mins** | 4.6 | 6.4 | 7.4 | 8.8 | 9.8 | 10.6 | 13 | 15.8 | 17.6 | 20.1 | 22.4 | 24.1 | 26.8 | 28.9 | 30.6 |
| **30 mins** | 6.2 | 8.5 | 9.7 | 11.4 | 12.6 | 13.5 | 16.4 | 19.7 | 21.8 | 24.8 | 27.4 | 29.4 | 32.5 | 34.8 | 36.8 |
| **1 hour** | 8.3 | 11.1 | 12.6 | 14.8 | 16.2 | 17.3 | 20.8 | 24.6 | 27.1 | 30.6 | 33.6 | 35.9 | 39.4 | 42.1 | 44.3 |
| **2 hours** | 11.2 | 14.7 | 16.5 | 19.1 | 20.8 | 22.1 | 26.3 | 30.8 | 33.7 | 37.7 | 41.1 | 43.8 | 47.7 | 50.8 | 53.3 |
| **3 hours** | 13.3 | 17.2 | 19.3 | 22.2 | 24.1 | 25.6 | 30.2 | 35.1 | 38.3 | 42.6 | 46.3 | 49.2 | 53.4 | 56.7 | 59.3 |
| **4 hours** | 15 | 19.3 | 21.5 | 24.7 | 26.7 | 28.3 | 33.2 | 38.5 | 41.9 | 46.5 | 50.4 | 53.4 | 57.9 | 61.3 | 64.1 |
| **6 hours** | 17.8 | 22.7 | 25.2 | 28.7 | 31 | 32.7 | 38.1 | 43.9 | 47.6 | 52.5 | 56.8 | 60 | 64.8 | 68.5 | 71.4 |
| **9 hours** | 21.2 | 26.7 | 29.4 | 33.4 | 35.9 | 37.8 | 43.8 | 50.1 | 54 | 59.4 | 64 | 67.4 | 72.6 | 76.5 | 79.6 |
| **12 hours** | 23.9 | 29.9 | 32.9 | 37.1 | 39.8 | 41.9 | 48.2 | 54.9 | 59.1 | 64.8 | 69.6 | 73.2 | 78.7 | 82.7 | 86 |
| **18 hours** | 28.4 | 35.2 | 38.5 | 43.2 | 46.2 | 48.4 | 55.4 | 62.6 | 67.2 | 73.3 | 78.4 | 82.3 | 88.1 | 92.4 | 95.9 |
| **24 hours** | 32.1 | 39.4 | 43 | 48 | 51.2 | 53.6 | 61 | 68.8 | 73.5 | 80 | 85.4 | 89.4 | 95.5 | 100 | 103.6 |

**Table 4 Depth Duration Frequency table generated for Derrybrien Wind Farm (depth in mm) (Fitzgerald, 2007)**

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Appendix 11A - Figure 11 -
Maximum flood depth for
100 year rainfall event



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As several turbine bases are located in areas that may be inundated in extreme events they are therefore located in Flood Zone A and the Justification Test for development management applies, as per Table 1. Application of the test to the site is discussed in Section VII.

Turbine T35 has been identified by ESB Engineering & Major Projects (EMP) engineers and the wind farm manager as being vulnerable to a sudden increase in groundwater level due to its depth of foundation, surface level and proximity to one of the existing drains leaving the site and potential blockage of a single 600 mm diameter culvert under the adjacent track downstream of T35. In response to this risk, an additional 600 mm diameter pipe was installed at this location along with a screen upstream of this to capture any removed peat and vegetation debris (Plate 3 and Plate 4). No other drainage issues have arisen in this area since these works were completed but it continues to be monitored closely.

It was noted in the first annual inspection following commissioning of the wind farm in 2006 that erosion of the banks adjacent to the drain between T32 and T35 had caused collapse of overlying peat into the drain crossing. This erosion was due to the high water velocities in this area which are associated with the steep channel gradients – according to the DEM the average gradient is 1:10 in this area. Therefore, it may be asserted that the outputs of the flood model corroborate the observations made in annual inspections since commissioning.

**1000-year rainfall event**

The FSU DDF model does not provide predicted rainfall depths beyond the 250-year return period. Fitzgerald (2007) stated that the model may be used with fair confidence for return periods up to 250 years but beyond this, model outputs should be treated with caution, especially for shorter durations.

For the purposes of assessing the flood risk to essential infrastructure, which as the Guidelines outline must be in Flood Zone C, the 1000 year storm event was calculated using the FSU methodology DDF equation:

$$\mathbf{R(T,D) = R(2.1)D^{s}(T-1)^{c_{24}+h(\ln D)}}$$

where

T = Rainfall return period (years);

D = Rainfall duration (days);

R(2,1) = median rainfall (mm), i.e. 2-year return period, 1 day event;

$c_{24}$ = shape parameter for 24-hour event;

s, h = dimensionless parameters dependent on R(2,1) and $c_{24}$.

Therefore, for T = 1000 years, D = 1 hour = 1/24 day –

$$\mathbf{R\left(1000,\frac{1}{24}\right) = R(2.1)D^{0.375}(1000-1)^{0.16+(-0.023)(\ln(\frac{1}{24})} = 59.9\ \boldsymbol{mm}}$$

With an additional allowance for climate change, the 1000 year rainfall is calculated to be 72.0 mm.

Given the uncertainty associated with extending out the model to this return period, a check against this value was made by fitting a curve to the 1-hour rainfall at Derrybrien up to the 250-

**Plate 3 Looking downstream at crossing near T35**

**Plate 4 Looking upstream at crossing near T35**

year return period and extrapolating to the 1000-year event (Figure 12). The growth curve for this duration approximates to a power trend line with equation –

$$\boldsymbol{R}\left(\mathbf{T},\frac{\mathbf{1}}{\mathbf{24}}\right)=\mathbf{12.45T^{0.230}}$$

The coefficient of determination or $R^2$ value is 1, indicating the values from the 10-year return period up to the 250-year return period have a perfect fit to this curve. This power equation maps closely to the form of the FSU equation for the 1-hour event at Derrybrien which can be simplified to –

$$\boldsymbol{R}\left(\mathbf{T},\frac{\mathbf{1}}{\mathbf{24}}\right)=\mathbf{11.97(T-1)^{0.233}}$$

The power equation produces a rainfall depth for the 1000-year event of 61 mm which increases to 73 mm when accounting for climate change.

Simulation of the 1000-year flood levels shows surface ponding to low depths in areas dispersed across the site (Figure 13). As with the 100-year return period, the most significant ponding occurs in the vicinity of T35. Given a number of turbine bases are located in areas that may be inundated in extreme events they are therefore located in Flood Zone B and the Justification Test for development management applies as per Table 1. Application of this test to the wind farm is discussed in Section VII.

**Estimation of culvert capacity at T35**

The flow rate in a drain due to an extreme event is calculated based on the rainfall intensity for such an event and the size of the upstream area. The upstream area associated with the channels in the vicinity of turbine T35 is 0.36 $km^2$.

Transport Infrastructure Ireland (TII, 2019) has recommended using the Agricultural Development and Advisory Service (ADAS) method for calculating design flows in catchments less than 0.4 $km^2$. This method was developed primarily for the sizing of field drainage pipes, itself based on the Transport and Road Research Laboratory (TRRL) method. This method takes into account the design storm rainfall and time of concentration for the required return period by using the Bilham formula. For the 75-year return period flow, $Q_{75}$ (in $m^3/s$) can be determined from:

$$\boldsymbol{Q_{75}=AREA(0.0443SAAR-11.19)SOIL^{2.0}\left[\frac{18.79T^{0.28}-1}{10T}\right]}$$

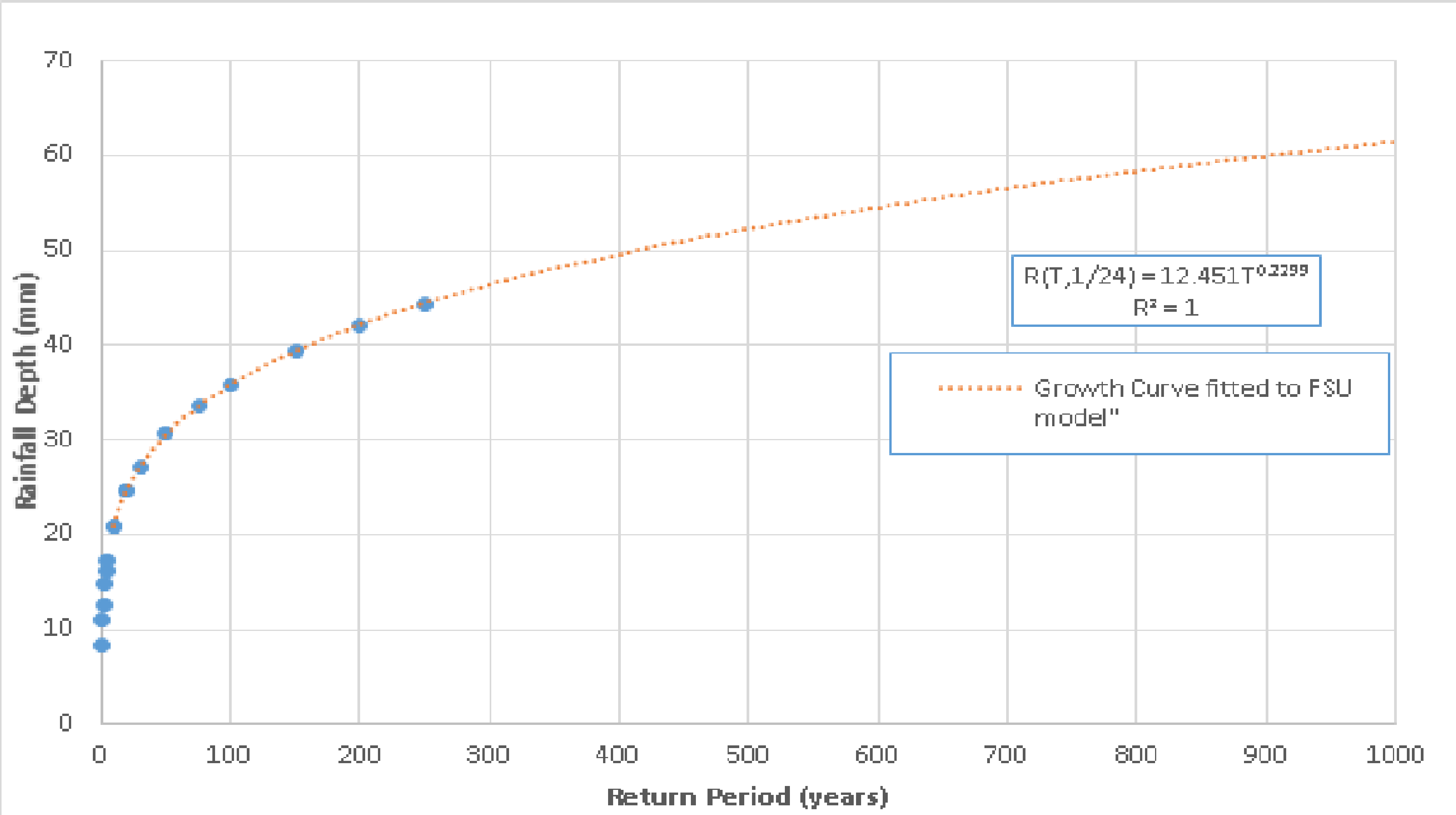
where

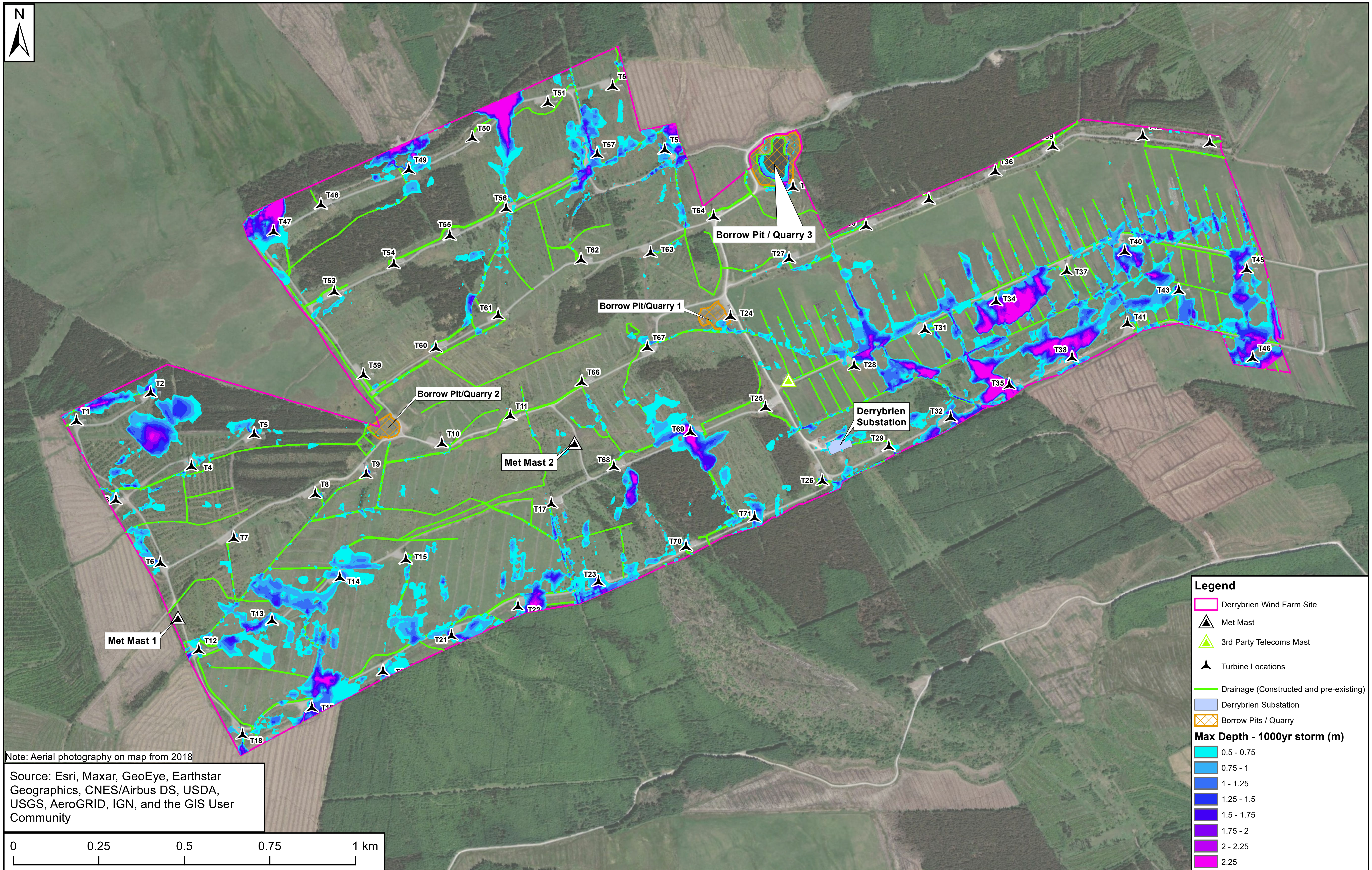
AREA (in $km^2$) is the catchment plan area.

SAAR (in mm) is the standard average annual rainfall for the particular location (obtained from Met Éireann). The Met Éireann SAAR model gives an estimate for the nearest node points to the summit of the site of 1573 and 1591 mm respectively.

SOIL is the soil index, defined as: $\boldsymbol{SOIL=\frac{(0.15S_1+0.30S_2+0.40S_3+0.45S_4+0.5S_5)}{1-S_u}}$

**Figure 12 Growth Curve for Derrybrien based on FSU Model**



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**Appendix 11A - Figure 13**
**Maximum flood depth for 1000 year rainfall event**



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$S_{1,2...}$ denote the proportions of catchment covered by each of the soil classes 1 to 5 and $S_u$ is the unclassified area of the catchment covered by water or pavement. Soil class 1 has a low runoff potential and soil class 5 has a high runoff potential. This can be obtained using the classifications in Table 5 and Table 6. Cawley & Cunnane (2003) recommend that the SOIL parameter should be determined on a site-by-site basis. For the Derrybrien wind farm site this approach was adopted, assessing the SOIL index on the basis of a combination of site inspection, mapped soil (i.e. well/poorly drained) and mapped aquifer potential (locally important / poorly productive). The Flood Studies Report (FSR) previously identified the upland mountainous regions of south Galway as having a soil class $S_5$ based on soil survey mapping of the UK and Ireland. Given the known shallow depth to the water table and extensive nature of the drainage on site both prior to and after completion of the wind farm Project the high runoff potential should be applied across the site. This corresponds to a SOIL index of 0.45.

| Drainage class | Depth to impermeable layer (cm) | Slope classes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 - 2° | | | 2 - 8° | | | >8° | | |
| | | Permeability rates above impermeable layers | | | | | | | | |
| | | Rapid (1) | Medium (2) | Slow (3) | Rapid (1) | Medium (2) | Slow (3) | Rapid (1) | Medium (2) | Slow (3) |
| 1 | >80 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 2 | 3 |
| | 40 - 80 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 |
| | <40 | — | — | — | — | — | — | — | — | — |
| 2 | >80 | 2 | 2 | 3 | 3 | 3 | 3 | — | 4 | 5 |
| | 40 - 80 | 2 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 5 |
| | <40 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 |
| 3 | >80 | | | 5 | 5 | 5 | 5 | — | 5 | 5 |
| | 40 - 80 | | 5 | 5 | 5 | 5 | 5 | — | 5 | 5 |
| | <40 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

**Table 5 The Classification of soils by winter rain acceptance rate from soil survey data copied from FSR Vol 1 (NERC, 1975)**

| General Soil Description | Runoff Potential | Soil Class |
|---|---|---|
| Well drained sandy, loamy or earthy peat soils<br>Less permeable loamy soils over clayey soils on plateaux adjacent to very permeable soils in valleys | Very low | $S_1$ |
| Very permeable soils (e.g. gravel, sand) with shallow groundwater<br>Permeable soils over rocks<br>Moderately permeable soils some with slowly permeable subsoils | Low | $S_2$ |
| Very fine sands, silts and sedimentary clays<br>Permeable soils (e.g. gravel, sand) with shallow groundwater in low lying areas | Moderate | $S_3$ |

| General Soil Description | Runoff Potential | Soil Class |
|---|---|---|
| Mixed areas of permeable and impermeable soils in similar proportions | | |
| Clayey or loamy soils | High | $S_4$ |
| Soils of the wet uplands:<br>Bare rocks or cliffs<br>Shallow, permeable rocky soils on steep slopes<br>Peats with impermeable layers at shallow depth | Very high | $S_5$ |

**Table 6 Runoff Potential and Soil Classes (TII, 2015)**

T is the time of concentration (in hrs) and is given using the ADAS method by:

$$T = 0.1677\frac{W^{0.78}}{Z^{0.39}}$$

where

W is the maximum catchment width (m). For the catchment to T35, this is 1500 m.

Z is the average height of the catchment divide above the discharge level (m). For the catchment to T35, this is 65 m.

The calculated $Q_{75}$ is therefore 1.6 $m^3/s$. As a comparison, the Rational Method was also adopted and, assuming a runoff coefficient (C) of 0.45 (i.e. fraction of rainfall converted to surface runoff), also returned a $Q_{75}$ of 1.6 $m^3/s$.

The channel in the vicinity of T35 was modelled in HEC-RAS to determine how the twin culvert pipes convey this flow rate. Assuming an additional 20% for future changes, a peak flow $Q_{100}$ value of 1.72 $m^3/s$ was adopted in running the model. The maximum flood levels over a 1-hour event are shown in Figure 14. At high flows (i.e. >1.5 $m^3/s$) flood levels are expected to overtop the access track rather than pool upstream at the turbine foundations for a short period (i.e. 15-30 minutes).

## Derrybrien 110 kV Substation

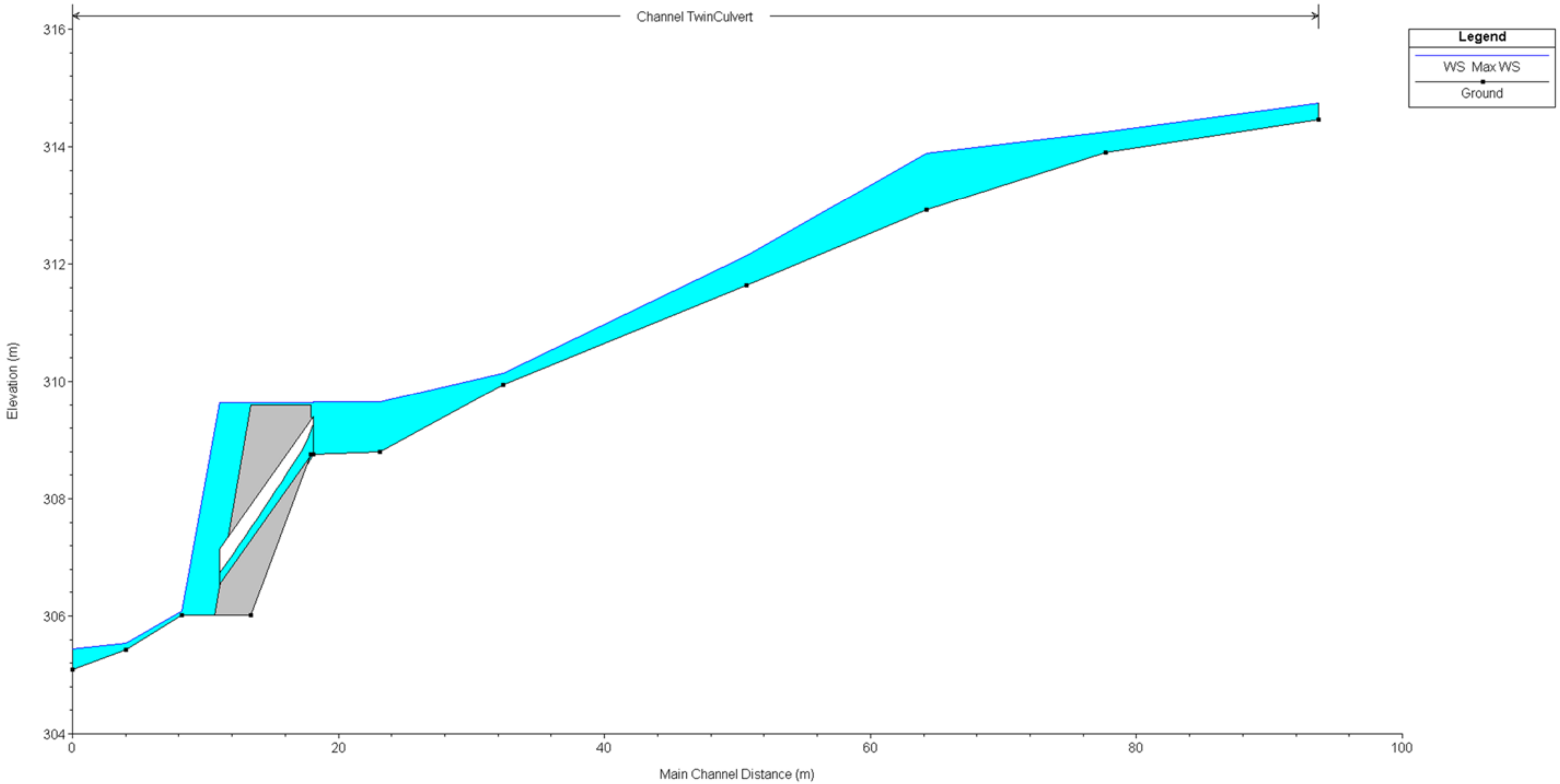
**Baseline Environment**

The 110-kV substation location prior to the wind farm project was in afforested land close to the boundary with extensively drained turbary land to the north. There was no existing drainage running through the site of the substation prior to the wind farm. The topography of the area is generally from northwest to southeast.

**Impact of Wind Farm Project on Flood Regime**

The substation element of the Project increased the impermeable area of the site and hence surface water runoff was slightly increased. This presented an increased risk of pluvial flooding on site and in the surrounding area were it not managed properly. Consideration was given to the existing surface water runoff route and the drainage characteristics in order to develop an appropriate site drainage system. Constructed drainage lines to the northwest at turbines T69

**Figure 14 Cross-section profile of maximum levels in channel at twin culverts near T35 for $Q_{100}$**



the substation which is diverted to the east and south before meeting a constructed drain close to the southeast of the substation. A constructed drainage line from T69 to T71 diverts to the south, surface water which may otherwise affect the substation area. As such, any surface runoff affecting the substation should constitute direct rainfall and / or overland flow from a small area (0.05 $km^2$ / 5 ha). The total fall between the top of this small catchment and the station is 17 m (347 mOD to 330 mOD) with an average gradient of 1:30 across the area.

The permeable area of substation compound constructed as part of the wind farm Project is finished on 50 mm single size clean compound stone. The permeable compound stone provides a means of attenuation for runoff and allows rainwater to infiltrate to ground as it would on Greenfield for this portion of the site. Rainwater from the roof of the control building, which is considered the highest quality runoff from hardstanding areas, connects via downpipes and drainage pipes away from the compound into the wind farm drainage system. The concrete access road within the compound is cambered to drain to the permeable compound stone. A deep drain to the southeast of the substation constructed as part of the Project conveys water using the natural steep gradient (approximately 1:10) via a culvert underneath the wind farm access track off-site to a pre-existing drain close to turbine T29 (Plate 5 and Plate 6). This pre-existing drain then conveys water to the southeast through steeply sloping Coillte forestry before joining the Derrybrien North River, a tributary of the Owendalulleegh River, just below the October 2003 slide area.

Figure 15 shows the predicted maximum inundation at the substation in the 1000-year return period rainfall event. In representing the substation in a 2-D inundation model, a different land cover type with a different Manning roughness coefficient was chosen to represent the substation compound and associated hardstanding as distinct from the drains and bog land in the vicinity. A time-lapse of the response to the critical (1 hour) storm event showed water draining away as expected without inundating to any significant level such that it would affect essential infrastructure within the substation. Inundation for short periods below 0.5 m does not pose a risk to the operation of the substation. The maximum depths in the event of this storm are above 0.5 m only at corners of the station which do not contain any electrical elements and do so for only a short period (i.e. minutes).

## Agannygal Substation

### Baseline Environment

The substation location prior to construction was in afforested Coillte-owned land. The land is elevated with respect to the surrounding area to the north, west and south. There is no record of pre-existing drainage or flooding issues on the site of the substation prior to construction and it is provisionally placed in Flood Zone C.

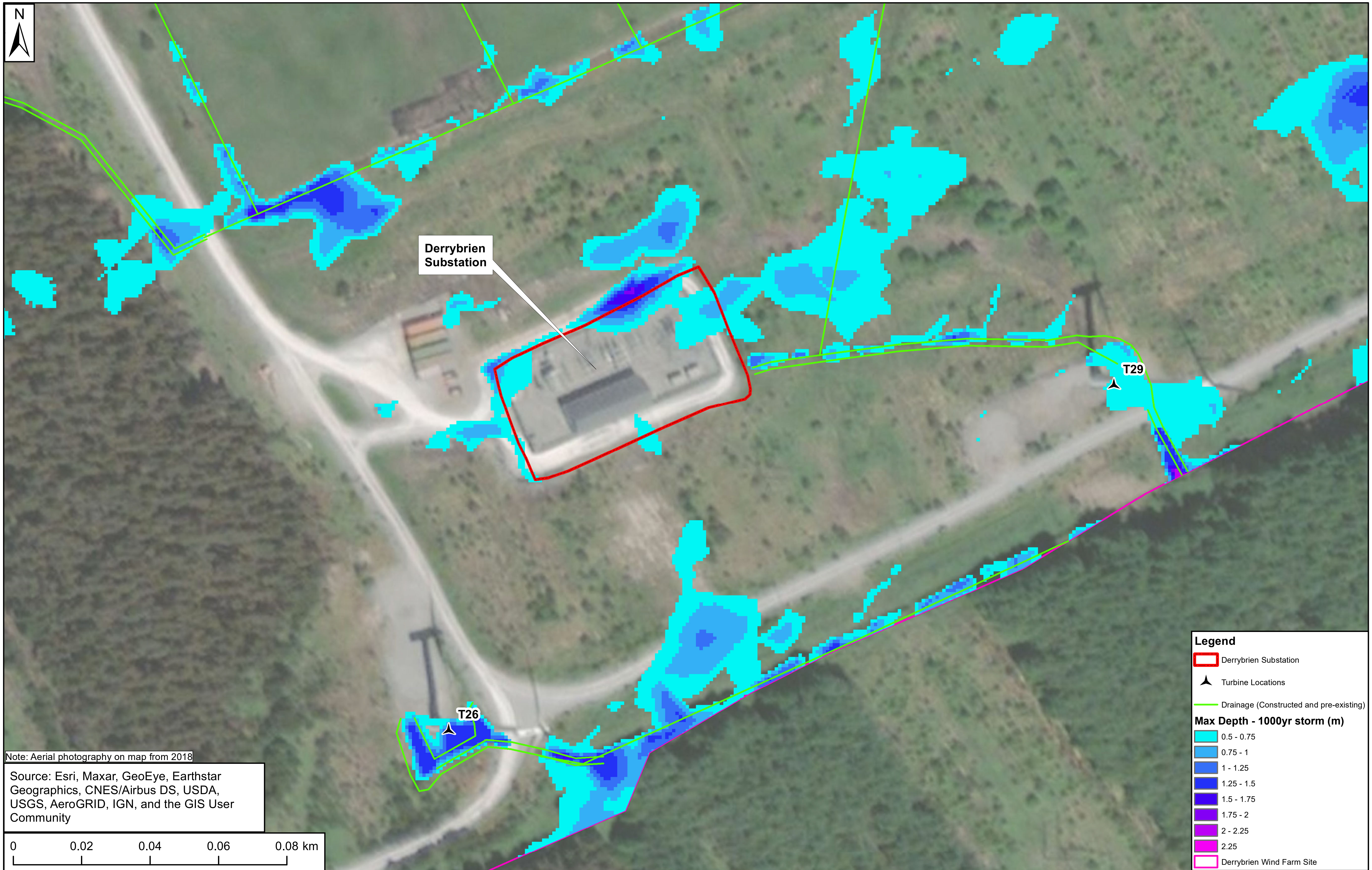
### Impact of Wind Farm Project on Flood Regime

As with Derrybrien 110 kV substation, the Agannygal substation increased the impermeable area of the site, bringing a slightly increased risk of pluvial flooding on site and in the surrounding area if not properly managed. The level of the station compound is 192.5 mOD.

The permeable area of substation site constructed as part of the wind farm Project is finished on 50 mm single size clean compound stone. The permeable compound stone provides a means of attenuation of runoff and allows rainwater to infiltrate to ground as it would on a

**Plate 5 Drainage channel downstream of substation**

**Plate 6 Continuation of channel downstream of substation**

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**Appendix 11A - Figure 15 - Maximum flood depths at substation for 1000 year rainfall event**



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Greenfield for this portion of the site. A system of land drains around the substation collects additional surface water drainage, particularly overland flow to the higher eastern boundary of the substation. Rainwater from the roof of the control building and from aco-channels around the impermeable tarmacadam entrance area connects into the substation drainage system. This water drains offsite as per Figure 16 where it leaves site with the land drainage.

Runoff then flows down a steep vegetated shallow channel next to the substation access road to where it joins with the local public road at an elevation of 181 m OD (Plate 7 and Plate 8). It is reasonable to assume that there would be an increase in runoff rates associated with the substation development. Rather than rainfall runoff being dispersed over the area, runoff from around the site is concentrated to a single flow path down a steep gradient to the local road. Based on the gradients on the access road (approximately 10% on average), in an extreme rainfall event flood waters would in all likelihood flow south across the road to the adjacent Coillte forestry ditch rather than ponding and blocking road access.

## OHL Route

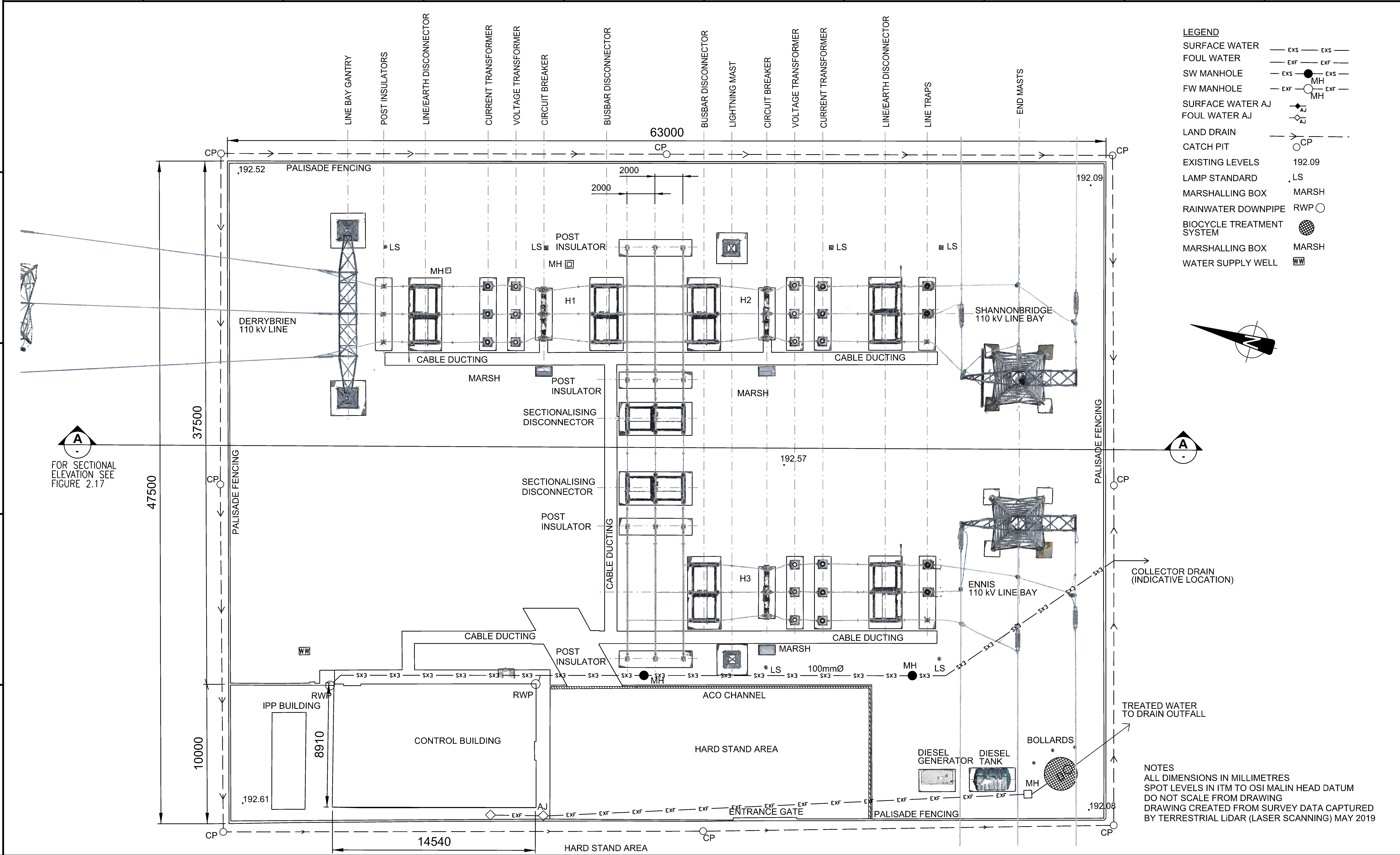
**Baseline Environment**

Several watercourses exist within the footprint of the OHL route, the largest being the Owendalulleegh River, approximately 6.0 m wide, which passes beneath the OHL between pole sets 25 and 26. Major drainage features tend to run east to west in the OHL corridor, with minor tributary features aligned approximately north to south to tie into the major drainage features.

**Impact of Wind Farm Project on Flood Regime**

There are several flat areas where local ponding of surface water occurs, e.g. Lough Agannygal located between Polesets 37 and angle mast 38. Streams and ditches have typically been regraded for use as forestry drainage where land use is commercial forestry. It is reported from Coillte data that this commercial forestry was established in the 1960s and 1970s. This is consistent with observations made on site that several areas have been clear felled and replanted over the years.

The polesets are considered to be water-compatible developments and as such, even in areas indicated as prone to flooding (Flood Zone A or B), carrying out the Justification Test is not required. According to PFRA map no. 195 (Figure 6), the indicative floodplains in the 100-year (1% AEP) event does not stretch far from the channel extents and as such does not reach the polesets on either side of any of the watercourses on the route.

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Purpose of issue - Preliminary unless indicated
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Client: GORT WIND FARMS LTD.

Project: DERRYBRIEN WIND FARM PROJECT

Contract:

Production Unit: CIVIL & ENVIRONMENTAL ENGINEERING

Drawing Title: APPENDIX 11.A - FIGURE 16
AGANNYGAL 110 kV SUBSTATION
LAYOUT PLAN

PLANNING



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Drawing Number: QS-000280-01-D460-012-024-000 (SHEET / REV)

**Plate 7 Looking north toward Agannygal substation**

**Plate 8 Channel downstream of Agannygal substation**

## V. Groundwater Flood Risk

Groundwater vulnerability represents the intrinsic geological and hydrogeological characteristics that determine how easily groundwater may be contaminated by activities at the surface. Vulnerability depends on the quantity of contaminants that can reach the groundwater, the time taken by water to infiltrate to the water table and the attenuating capacity of the geological deposits through which the water travels. The Geological Survey of Ireland (GSI) groundwater vulnerability rating of the aquifer underlying the site ranges from Moderate in the south-west corner of the site to High over most of the site. The High pollution vulnerability rating suggests that the general overburden, i.e. combined thickness of peat and mineral subsoils, at the site ranges from 3 – 5 m in these areas (Table 7). Ground investigation information showed the depth to the top of the rock was variable but typically ranged from 3.5 – 6.2 m, which generally reflects the GSI vulnerability classification of High and Moderate. However, the rock was shallower (between 1.3 m and 2.9 m) at the northern part of the site representing extreme vulnerability as per Table 7 and there were some locally deeper depths to rock (8 – 9.1 m) at the north-eastern and central parts of the site.

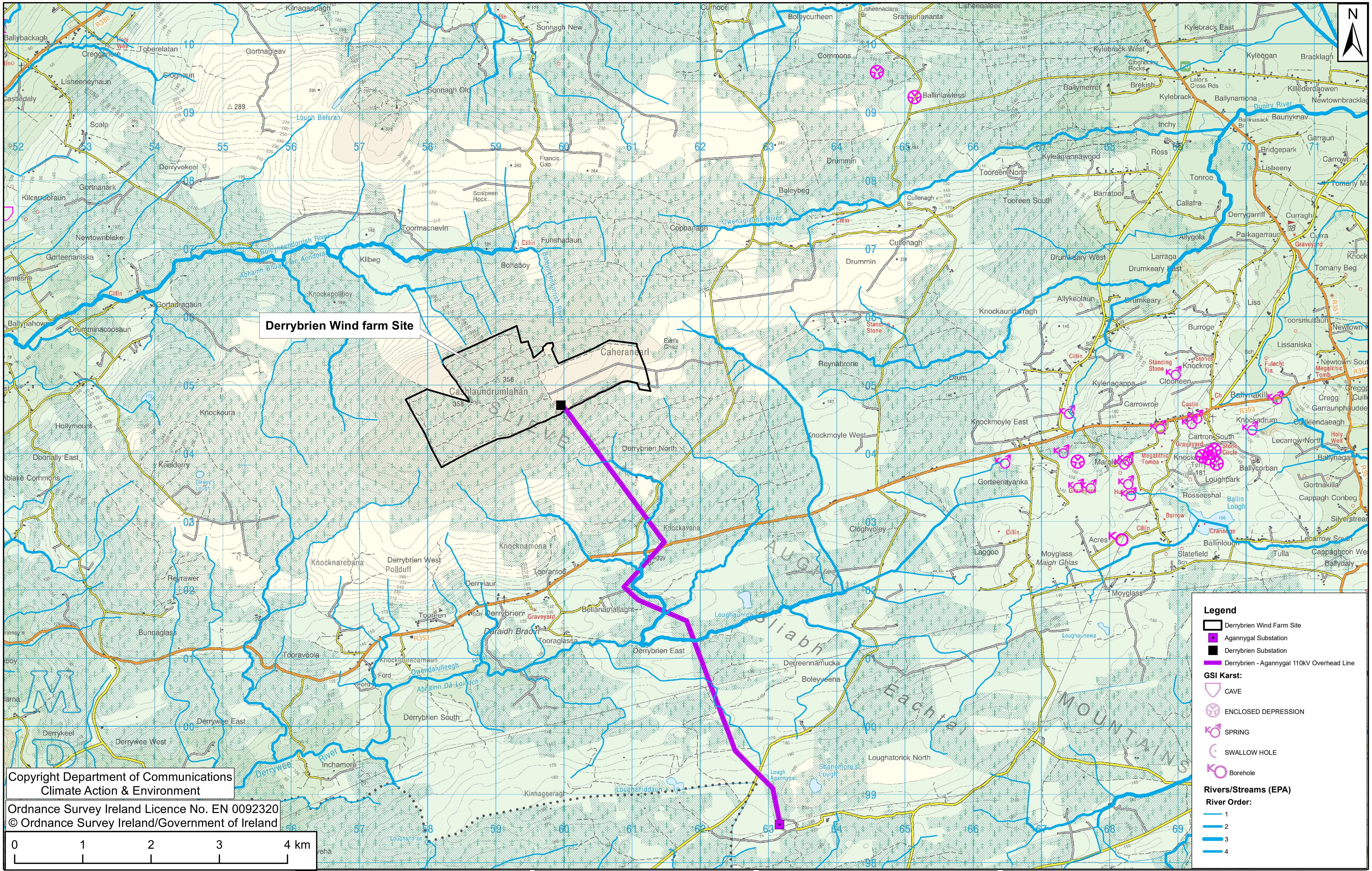
| Sensitivity | Hydrogeological Conditions | | | | |
|---|---|---|---|---|---|
| | Subsoil Permeability (Type) and Thickness | | | Unsaturated Zone | Karst Features |
| | High Permeability (Sand and Gravel) | Medium Permeability (Sandy Subsoil) | Low Permeability (Clayey Subsoil/Peat) | Sand and Gravel aquifers only | <30 radius |
| Extreme (E) | 0 – 3.0 m | 0 – 3.0 m | 0 – 3.0 m | 0 – 3.0 m | - |
| High (H) | >3.0 m | 3.0 – 10.0 m | 3.0 – 5.0 m | >3.0 m | N/A |
| Moderate (M) | N/A | >10.0 m | 5.0 – 10.0 m | N/A | N/A |
| Low (L) | N/A | N/A | >10.0 m | N/A | N/A |

**Table 7 GSI Groundwater Vulnerability to Pollution Categories**

The Ayle River Formation, comprising Devonian mudstones, siltstones and conglomerates, underlies most of the wind farm site. This bedrock formation is predominantly classified by the GSI (www.gsi.ie) as a poor bedrock aquifer (PI), having bedrock that is generally unproductive except for local zones. This bedrock is a muddy impermeable bedrock that is not very conducive to transmitting and storing groundwater flow. There are no mapped fault lines traversing the site.

The upland areas comprise blanket peat, which underlies all the forestry in the area, with acid brown earths/brown podzolics and peaty gleys acidic underlying most of the agricultural lands farther down the valleys in both the Boleyneendorrish and Owendalulleegh catchments.

There are no mapped karst features associated with these Devonian Old red sandstones and conglomerates. The closest karst features to the Project area according to GSI mapping are a number of springs and depressions near Ballynakill, approximately 5 km to the southeast of the wind farm site at its closest point (Figure 17). These springs are at the source of the

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DRAWING TITLE: Appendix 11A - Figure 17 - Karst features in relation to wind farm project

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Owendalulleegh River where the bedrock is a combination of dark muddy limestone / shale and massive unbedded lime-mudstone.

Groundwater on the wind farm can reasonably be expected to flow downslope through a network of natural open pipes within the peat as well as possibly through an open joint network in the underlying bedrock. Several springs have been identified on site, particularly within scarp faces on the northern slopes. Linear tree patterns such as in the south-western corner of the site shown in Figure 8 is possibly indicative of areas where subsurface flow was concentrated.

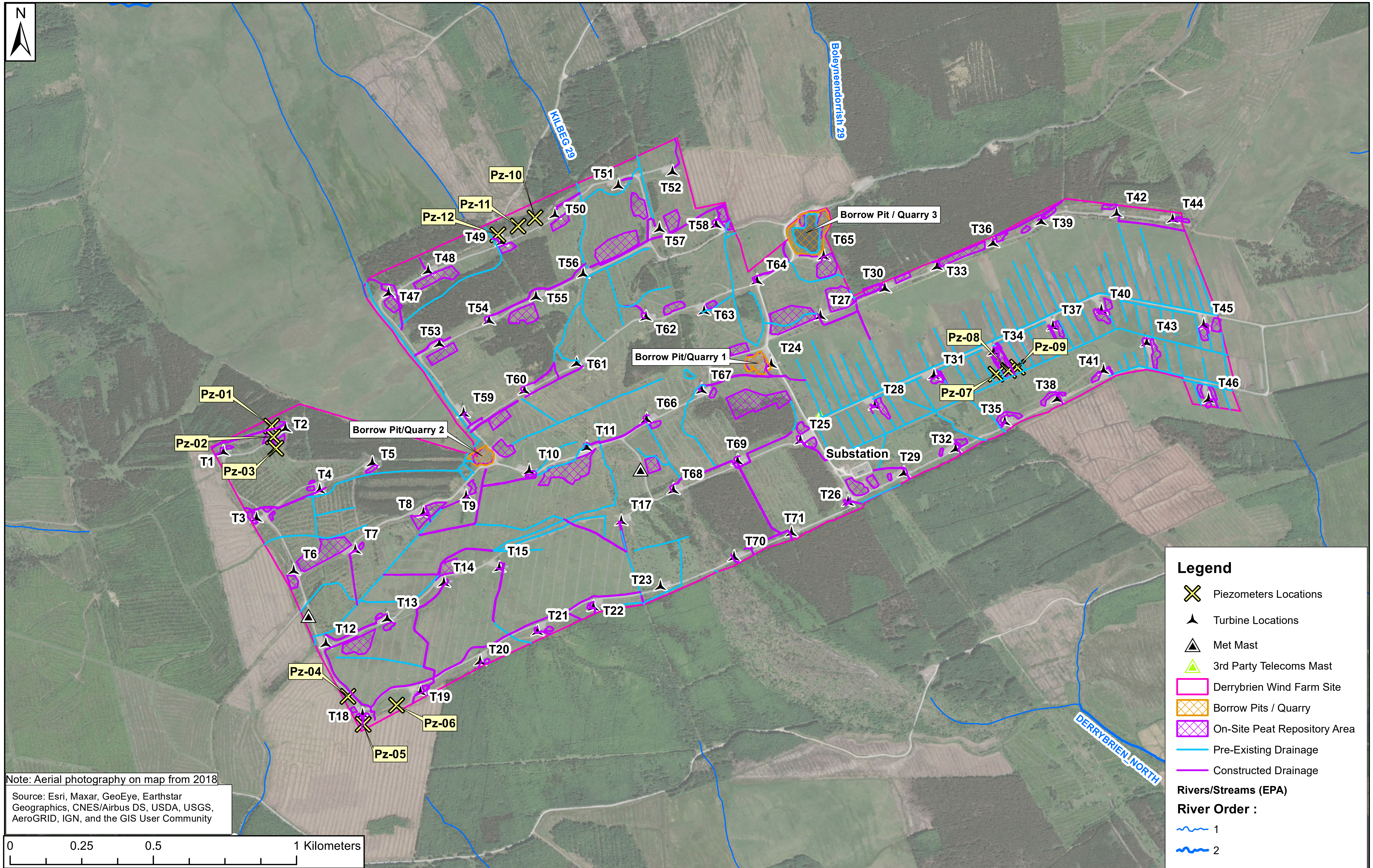
During construction, standpipes were installed by AGL Consulting Ltd. at 6 no. locations along a north-south axis from the centre to the south of the site in the vicinity of the peat slide to get a profile of the depth of groundwater down the slope. The readings that were taken from 17th November to 4th December 2003 indicated that the depth to groundwater ranged from 0.1 m to 1.1 m below ground level (BGL).

In addition to this, 12 no. electronic vibrating-wire piezometers were also installed to the base of the peat layer in clusters of three at 4 No. locations across the site to provide continuous readings of water levels in the peat. At each of these locations, newly constructed drainage could be expected to result in a fall in groundwater levels in the years following their excavation. The piezometers were installed adjacent to turbines T2 and T18 near the western boundary and near T34 in the middle of the former turbary land at the eastern end of the site (Figure 18). Piezometers installed at the northern end of the site at T49 / T50 malfunctioned and provided no useful measurements. The piezometers indicated that the depth to groundwater generally fluctuated between 0.3 and 1.1 mBGL at the end of construction in 2005, which was consistent with the pre-construction site investigation.

| Piezometers / Turbine No. | Piezo Distance from Nearest Drain (m) | Drain depth (m) | Average fall in Groundwater Level 2005-2012 (m)(range) | Years of data |
|---|---|---|---|---|
| P1 – P3 / T2 | 4.5 | 0.85 | 0.7 (0.6 – 0.8) | Jan-05 to Nov-11 |
| P4 – P6 / T18 | 13 | 1.4 | 0.4 (0.2 – 0.6) | Jan-05 to Nov-11 |
| P7 – P9 / T34 | 5 | 1.3 | 0.6 (0.4 – 0.85) | Jan-05 to Feb-10 |

**Table 8 Summary information of piezometers installed on site between 2005 and 2011**

In the years following commissioning, groundwater levels in the peat at these piezometers gradually reduced by between 0.2 and 0.85 m (Figure 19). This gradual reduction is consistent with the very low permeability and correspondingly slow reaction time of groundwater levels in peat to newly excavated drainage lines. The ultimate reduction in groundwater levels was dependent on the depth to which the channels were excavated and the distance of measuring points from the channels (Table 8). For instance, piezometers 4 – 6 are further away from the nearest excavated drains and therefore have taken longer to reduce towards a final drawdown level. Piezometers 1 – 3, given their relative proximity to newly excavated drainage, should

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DRAWING TITLE: Appendix 11A - Figure 18 - Approximate Locations of Piezometers on Site 2005-2011



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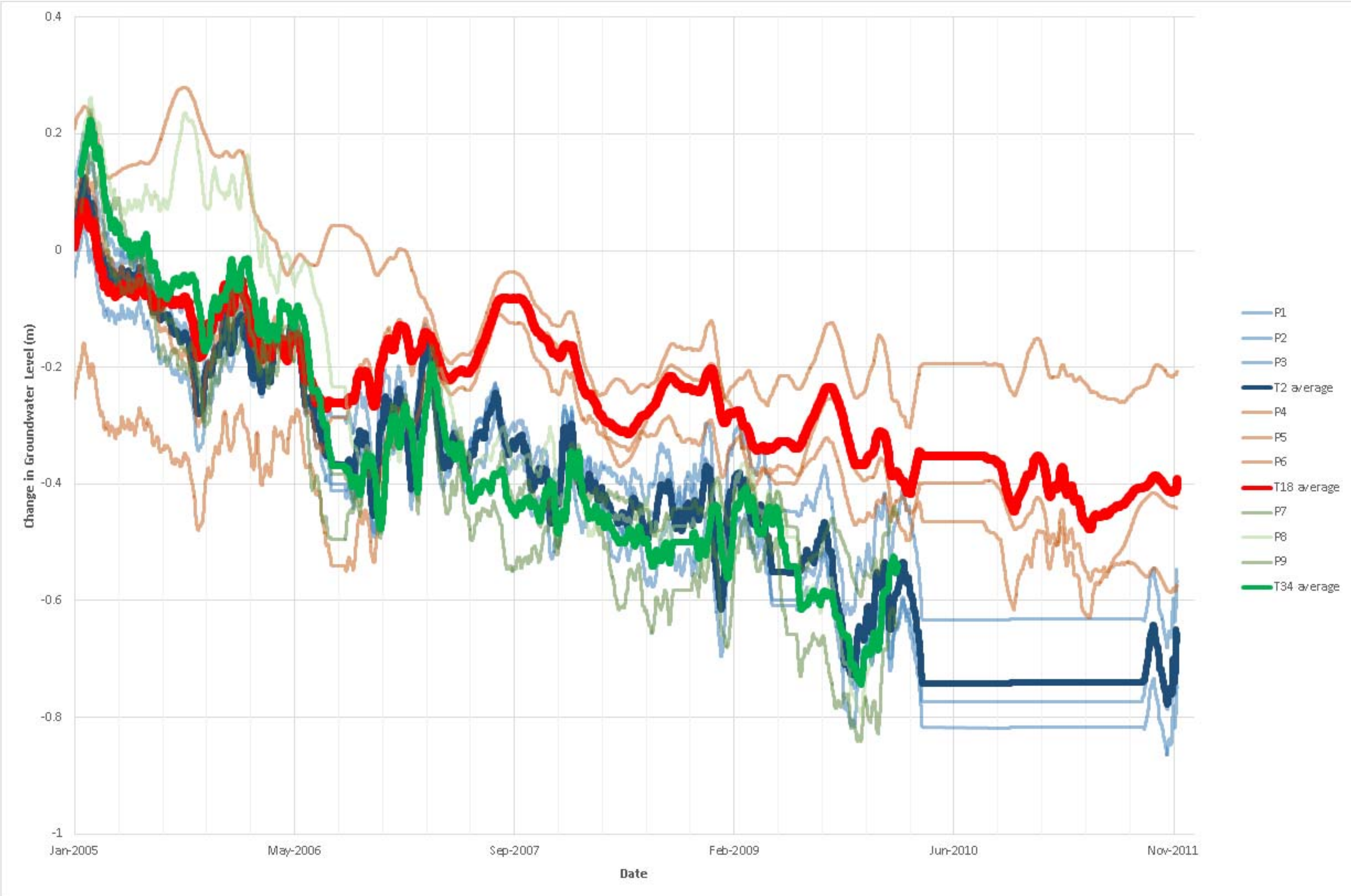
**Figure 19 Changes in groundwater level relative to baseline 2005-2011**



stabilise at no lower than 0.85 mBGL. Given the baseline level in this area was close to the surface it was already close to stabilising by the end of 2011. At T34 the nearby drain was a pre-existing turbary drain which was likely cleaned out and was most likely deepened as part of the wind farm construction, resulting in the drawdown in groundwater levels.

As no further drainage has been installed on site and no measures have been taken to restore the baseline groundwater levels by blocking or infilling drains in the meantime, it is likely that groundwater levels across the site have stabilised over the intervening years since 2012. In general, the vast majority of dewatering of the peat took place in the early years following construction, but the degree and rate of change would have varied significantly with the greatest changes most likely taking place in the southwest of the site where most of the new drainage channels were introduced while the relatively undisturbed areas such as the peatland and lake between T62 and T67 in the centre of the site undergoing little evident change and remaining largely intact.

The fall in groundwater levels was consistent and gradual at a rate of approximately 0.1 m/year (or 0.03 l/s per ha) across the site and would not have any significant impact on the downstream environment with respect to flood risk, given that falls in groundwater level are not correlated with periods of high surface water runoff. There is also no reason to believe there is a groundwater flood risk to the wind farm site given the general reduction in groundwater levels.

### Derrybrien 110 kV Substation

The substation is located within the wind farm site. As discussed above there is no reason to believe groundwater poses a flood risk to the substation.

### Agannygal Substation

As with the wind farm site, the Ayle River Formation comprising a muddy impermeable bedrock underlies the substation site. As with the wind farm, no mapped fault lines traverse the site. The GSI groundwater vulnerability rating of the underlying aquifer is classified as High suggesting that the total thickness of the soil is 3 – 5 m in this area. There are no mapped karst features and no mapped groundwater sources within the vicinity of the site. There is no reason to believe groundwater poses a flood risk to the site.

### OHL Route

Based on information from the GSI database, the majority of the OHL route is underlain by rock which is considered a poor aquifer (bedrock which is generally unproductive except for local zones). However, the segment of the route underlain by Visean Limestone (between pole set 23 and 26 approximately) is considered a locally important aquifer (bedrock which is moderately productive only in local zones) although no evidence for groundwater usage from this aquifer has been found. Groundwater vulnerability ranges from low to extreme in pockets of the most low-lying areas across the OHL route due to the shallow depth to bedrock in these areas. There are no mapped karst features in these areas. Groundwater poses no flood risk to this element of the Project.

## VI. Impact on Current Flood Regime in Downstream Watercourses

None of the streams draining from the wind farm site are gauged due to their very small size and low importance. The nearest hydrometric gauging station (measuring flow / water level) is located on the Owendalulleegh approximately 15 km downstream at Killafeen, 1 km upstream of Lough Cutra, station no. 29023. Therefore, the calculated discharge to the major rivers from each subcatchment for a mean annual flood (commonly denoted QBAR) requires use of a flood estimation method based on catchment characteristics that is not calibrated against site specific observed data.

A range of methods of estimating runoff rates – both runoff type and flow frequency methods – have been reviewed previously by Cawley & Cunnane (2003). The rainfall runoff methods reviewed include the rational method (considered most appropriate for very small catchments), the FSR unit hydrograph design rainstorm method and the Ministry of Forestry and Food (MAFF) method, while the flow frequency methods include those described in the FSR, Flood Studies Supplementary Report (FSSR 6), Institute of Hydrology (IH) 124, Flood Estimation Handbook (FEH) and Flood Studies Update (FSU).

It is recommended by Transport Infrastructure Ireland (TII, 2019) to use one of two methods depending on the size of the catchments in question:

a) The IH124 Method for catchments > 0.4 km$^2$; and

b) The ADAS Method for catchments ≤ 0.4km$^2$.

The wind farm site partially extends over the catchments of three rivers – Boleyneendorrish, Duniry and Owendalulleegh and can be divided into a number of tributary subcatchments draining to each of the rivers (Figure 10)**Error! Reference source not found.**. Given the area of the respective subcatchments at the point at which they join the rivers offsite, the IH124 Method was selected to estimate the average annual flow.

The IH124 Method (Marshall & Bayliss, 1994) is dedicated to the hydrology catchments less than 25 km$^2$. A regression equation was produced to calculate QBAR in m$^3$/s:

$$Q_{BAR} = 0.00108 AREA^{0.89} SAAR^{1.17} SOIL^{2.17}$$

The catchment descriptors adopted to calculate QBAR using the IH124 Method are summarised in Table 9.

| Subcatchments | SC1 | SC2 | SC3 | SC4 | SC5 | SC6 | SC7 | SC7(a) | SC7(b) | SC7(c) | SC8 | SC9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area (AREA) km² | 6.44 | 3.17 | 0.96 | 1.74 | 2.22 | 5.14 | 13.04 | 5.87 | 3.02 | 3.55 | 2.81 | 6.48 |
| Annual Average Rainfall (SAAR) mm | 1284 | 1269 | 1275 | 1275 | 1285 | 1308 | 1305 | 1308 | 1308 | 1297 | 1285 | 1274 |
| Soil Index (SOIL) | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| Area within Site km$^2$ | 0.31 | 0.525 | 0.223 | 0.09 | 0.013 | 0.059 | 2.126 | 0.23 | 1.11 | 0.786 | 0.044 | 0.05 |

**Table 9 Areas for each of the subcatchments draining from wind farm site**

The FSU methodologies are now recommended by the OPW as being the preferred method for extreme rainfall and flood estimation in Ireland and has become the accepted norm for application on rivers and streams that are ungauged. The FSU model estimates QMED (the median annual flood, usually the bank-full condition) at ungauged sites using the following seven variable equation:

$$QMED_{rural} = 1.237 \times 10^{-5}\ AREA^{0.937}\ BFISOIL^{-0.922}\ SAAR^{1.306}\ FARL^{2.217}\ DRAIND^{0.341}\ S1085^{0.185}(1+ARTDRAIN2)^{0.408}$$

QMED ($m^3/s$) is the index flood used in the FSU methodologies. The index flood is a reference flood that can be relatively reliably estimated from gauged data which for FSU methodologies is the median of floods in the annual maximum (A-max) series for a given location. QMED is said to have a return period of two years on the annual maximum scale of frequency. The factorial standard error associated with the FSU method is 1.37 which compares favourably to the IH124 (error = 1.65), FSSR 6 (1.48) and FEH (1.55).

$QMED_{rural}$ is estimated from seven catchment descriptors:

i) AREA = drainage area (km²)

ii) BFISOIL = catchment soil and geology index

iii) SAAR = average annual rainfall (mm)

iv) FARL = an index of flood attenuation by reservoirs and lakes

v) DRAIND = an index of drainage density

vi) S1085 = the mainstream slope (m/km)

vii) ARTDRAIN2 = length of upstream network included in OPW scheme channels (km).

A data analysis was carried out by the OPW as part of the FSU Work Packages (OPW, 2012) to evaluate a number of flow estimation methods for small catchments. These included the 7-variable FSU equation above and a 3-variable FSU equation. The 7-variable method was judged not to be suitable for catchments at the scale of interest. The 3-variable equation was modified to become a new regression equation called the FSU4.2a equation:

$$QMED_{rural}=2.0951 \times 10^{-5}\ AREA^{0.9245}\ SAAR^{1.2695}\ BFI^{-0.9030}\ FARL^{2.3163}\ S1085^{0.2513}$$

The nearest downstream ungauged catchment nodes on the ‘Flood Frequencies’ module in the FSU portal were used to estimate the baseline discharge magnitude $QMED_{rural}$ (Table 10).

| | FSU ungauged subject site no. | AREA ($km^2$) | SAAR (mm) | BFI | FARL | S1085 | $QMED_{rural}$ ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| SC1 | 29_390_3 | 6.44 | 1274 | 0.40 | 1 | 28.71 | 5.45 |
| SC2 | 29_577_4 | 3.17 | 1266 | 0.40 | 1 | 38.07 | 3.02 |
| SC3 | 29_566_2 | 0.96 | 1270 | 0.45 | 1 | 50.00 | 0.97 |
| SC4 | 29_590_2 | 1.74 | 1275 | 0.45 | 1 | 73.48 | 1.85 |
| SC5 | 25_940_3 | 2.22 | 1270 | 0.45 | 1 | 36.02 | 1.93 |
| SC6 | 29_372_9 | 5.14 | 1302 | 0.44 | 1 | 28.95 | 4.19 |
| SC7 | 29_327_2 | 13.04 | 1308 | 0.44 | 1 | 23.84 | 9.48 |
| SC7(a) | 29_330_6 | 5.87 | 1312 | 0.44 | 1 | 27.40 | 4.71 |
| SC7(b) | 29_278_6 | 3.02 | 1309 | 0.44 | 1 | 43.87 | 2.86 |
| SC7(c) | 29_322_5 | 3.55 | 1300 | 0.44 | 1 | 52.76 | 3.45 |
| SC8 | 29_179_2 | 2.81 | 1290 | 0.41 | 1 | 78.21 | 3.24 |
| SC9 | 29_292_5 | 6.48 | 1277 | 0.41 | 1 | 79.67 | 6.95 |

**Table 10 $QMED_{rural}$ calculated using FSU4.2a equation**

The $QMED_{rural}$ value must be adjusted by using data from a similar gauged catchment – a Pivotal Site. This can be either the nearest downstream or upstream gauge on the same river, the nearest gauged catchment, selected from the user's knowledge of the subject catchment, or selected on the basis of hydrological similarity using AREA, SAAR and BFI values.

For each of the subcatchments, the gauge downstream on the Owendalulleegh River at the inlet to Lough Cutra (gauge no. 29071) was chosen as the pivotal site.

$$\textit{Piv. Adjfac} = QMED_{gauged} / QMED_{rural}$$

The FSR-based methods such as IH124 calculate QBAR while the Flood Studies Update uses QMED as the index flood. The introduction to the FSR suggests a relationship between QBAR and QMED where:

***QBAR = 1.07 x QMED*** (Table 11)

| | FSU ungauged subject site no. | FSU $QMED_{rural}$ | Piv. Adjfac $QMED_{rural}$ | FSU $QMED_{adj}$ | FSU $QBAR_{adj}$ (=1.07*QMED) |
|---|---|---|---|---|---|
| SC1 | 29_390_3 | 5.45 | 0.83 | 4.54 | 4.86 |
| SC2 | 29_577_4 | 3.02 | 0.83 | 2.51 | 2.69 |
| SC3 | 29_566_2 | 0.97 | 0.83 | 0.81 | 0.86 |
| SC4 | 29_590_2 | 1.85 | 0.83 | 1.54 | 1.65 |
| SC5 | 25_940_3 | 1.93 | 0.83 | 1.61 | 1.72 |
| SC6 | 29_372_9 | 4.19 | 0.83 | 3.49 | 3.73 |
| SC7 | 29_327_2 | 9.48 | 0.83 | 7.90 | 8.45 |
| SC7(a) | 29_330_6 | 4.71 | 0.83 | 3.93 | 4.20 |
| SC7(b) | 29_278_6 | 2.86 | 0.83 | 2.38 | 2.55 |
| SC7(c) | 29_322_5 | 3.45 | 0.83 | 2.87 | 3.08 |
| SC8 | 29_179_2 | 3.24 | 0.83 | 2.70 | 2.89 |
| SC9 | 29_292_5 | 6.95 | 0.83 | 5.79 | 6.20 |

**Table 11 Estimated average annual flows ($m^3/s$) for each subcatchment using FSU4.2a method**

The estimated QBAR figure derived from the FSU methodologies is compared to that calculated using the IH124 method in Table 12. The FSU derived QBAR is generally higher, between 2% and 43% higher; 15% higher on average.

| Subcatchment | FSU QBAR ($m^3/s$) | IH124 QBAR ($m^3/s$) | Ratio of FSU : IH124 |
|---|---|---|---|
| SC1 | 4.86 | 4.34 | 1.12 |
| SC2 | 2.69 | 2.28 | 1.18 |
| SC3 | 0.86 | 0.79 | 1.09 |
| SC4 | 1.65 | 1.34 | 1.23 |
| SC5 | 1.72 | 1.69 | 1.02 |
| SC6 | 3.73 | 3.63 | 1.03 |
| SC7 | 8.45 | 8.29 | 1.02 |
| SC7(a) | 3.34 | 4.09 | 1.03 |
| SC7(b) | 3.54 | 2.26 | 1.13 |
| SC7(c) | 3.08 | 2.59 | 1.19 |
| SC8 | 2.89 | 2.08 | 1.39 |
| SC9 | 6.20 | 4.33 | 1.43 |

**Table 12 Comparison of estimated average annual flows from IH124 and FSU methods for subcatchments connected to wind farm site**

For the subcatchments associated with the wind farm the time of concentration, calculated Bransby Williams formula, ranges from 45 to 160 minutes between the smallest and largest catchments. As such, any flooding effects for the wind farm pre-construction are thought to be brief (i.e. less than a day) at the subcatchment level.

## Estimated impacts of hardstanding

The rainfall runoff response of a catchment can be significantly altered by urbanisation where impervious surfaces inhibit infiltration and reduce surface retention, resulting in an increase in surface runoff volume combined with an increase in the rapidity of the response. Each of the subcatchments (SC1 – SC9) draining to the major rivers (Owendalulleegh, Boleyneendorrish and Duniry) has an upstream area that includes part of the wind farm site. Within each respective subcatchment the road and concrete hardstanding areas were measured to estimate the urbanised extent of the subcatchment.

In assessing the effects of urbanisation it is the change in catchment response that is sought, with the rural model, described above, assumed to be capable of predicting this response for the catchments in the FSU dataset. The FSU urban adjustment factor can be used to supplement the performance of the rural model for catchments that have undergone at least partial urbanisation (Murphy, 2009).

The FSU4.2a regression equation adopted above can take into account urban extent with a catchment in the same manner as in the general FSU method, i.e.:

$$QMED = QMED_{adjusted} \times (1+URBEXT)^{1.482}$$

where URBEXT is simply the proportion of the catchment which has been urbanised.

The URBEXT factors for each subcatchment are small and have no significant effect on QMED values down to the major rivers (Table 13).

| | AREA ($km^2$) | Roads and Concrete Area ($km^2$) | Subcatchment urbanised (%) | FSU QMED ($m^3/s$) | FSU QMED with |
|---|---|---|---|---|---|
| SC1 | 6.44 | 0.012 | 0.18% | 4.54 | |
| SC2 | 3.17 | 0.019 | 0.61% | 2.51 | |
| SC3 | 0.96 | 0.010 | 1.06% | 0.81 | |
| SC4 | 1.74 | 0.007 | 0.38% | 1.54 | |
| SC5 | 2.22 | 0.001 | 0.06% | 1.61 | |
| SC6 | 5.14 | 0.004 | 0.08% | 3.49 | |
| SC7 | 13.04 | 0.071 | 0.55% | 7.90 | |
| SC7(a) | 5.87 | 0.038 | 0.65% | 3.93 | |
| SC7(b) | 3.02 | 0.008 | 0.28% | 2.38 | |
| SC7(c) | 3.55 | 0.025 | 0.70% | 2.87 | |
| SC8 | 2.81 | 0.001 | 0.05% | 2.70 | |
| SC9 | 6.48 | 0.003 | 0.05% | 5.79 | |

**Table 13 Calculated change in QMED for each subcatchment due to addition of wind farm hardstanding areas**

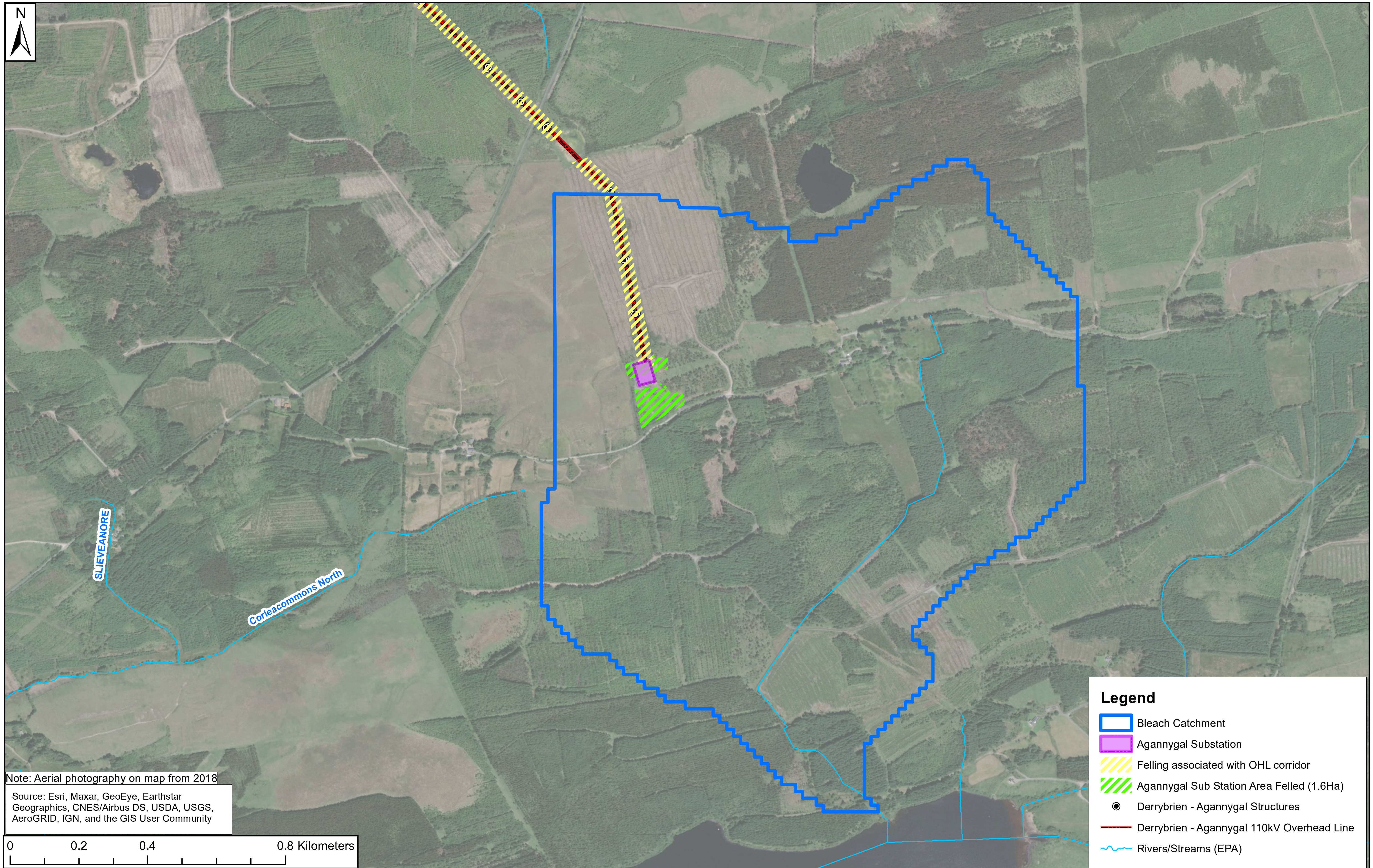
It should be noted that this urban adjustment factor assumes the urbanised areas are impervious surfaces which inhibit infiltration and reduce surface water retention. However, the use of floating road, which accounts for 18.8 km of the 19.7 km of on-site access tracks (the 2.0 km of tracks existing on site prior to the Project was all floating), facilitates rainwater infiltration into the peat layer beneath. Any additional rainwater which does not infiltrate can spill over the edge into the undisturbed peat. Floating roads are sympathetic to the natural drainage as they do not act as a barrier nor as a deep wide permeable drain that would dewater the adjacent saturated peat into its formation layer and convey elsewhere with the gradient of the road.

Similarly, for Agannygal substation, which lies in the Bleach catchment in the Shannon IRBD, urbanised areas including access track and compound amounted to less than 0.01 $km^2$, approximately 0.35% of the catchment area down to Lough Atorick (Figure 20).

## Estimated impacts of constructed drainage

Circa 12 km of drains were constructed on site as part of the wind farm project which effectively maintained overland flow paths which may otherwise have been obstructed by new turbine hardstanding and roads. Culverts were also constructed at various access track crossings so as to maintain the conveyance path of the existing and constructed drains crossed and thus prevent excessive ponding of water on the uphill sides of these roads. The culverts installed were necessary to maintain the drainage runs and avoid unnecessary diversion of drainage on the site. This increased the overall length of the drainage network in a given subcatchment.

The natural runoff characteristics of this upland site prior to the project would be classified as a high flood runoff site (SOIL index 0.45). The effect of the new drainage runs and deepening of existing drains, as a worst-case assessment, is to increase the runoff class of the wind farm

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PROJECT: Derrybrien Wind Farm Project

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DRAWING TITLE: **Appendix 11A - Figure 20 - Catchment draining from Agannygal substation**



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site from high runoff to very high runoff (SOIL index 0.05). This effect increases the peak flood rate as opposed to the total flood volume which will remain similar.

The impact of this on QMED is to increase it compared to pre-project value by 0 – 9% depending on the fraction of each subcatchment within the wind farm site boundary (Table 14). Similarly, by reducing the BFI value in the FSU equation by a similar factor (0.07) the expected QMED is increased in proportion with the share of each subcatchment belonging within the wind farm (Table 15).

| | Pre-existing QBAR ($m^3/s$) | Increased QBAR ($m^3/s$) | Change ($m^3/s$) | Change (%) |
|---|---|---|---|---|
| SC1 | 4.34 | 4.39 | 0.05 | 1.2% |
| SC2 | 2.28 | 2.37 | 0.09 | 4.0% |
| SC3 | 0.79 | 0.84 | 0.05 | 5.7% |
| SC4 | 1.34 | 1.36 | 0.02 | 1.3% |
| SC5 | 1.69 | 1.69 | 0.00 | 0.1% |
| SC6 | 3.63 | 3.64 | 0.01 | 0.3% |
| SC7 | 8.29 | 8.62 | 0.33 | 4.0% |
| SC7(a) | 4.09 | 4.13 | 0.04 | 0.9% |
| SC7(b) | 2.26 | 2.47 | 0.21 | 9.1% |
| SC7(c) | 2.59 | 2.73 | 0.14 | 5.4% |
| SC8 | 2.08 | 2.09 | 0.01 | 0.4% |
| SC9 | 4.33 | 4.34 | 0.01 | 0.2% |

**Table 14 Changes in IH124-calculated QBAR due to constructed drainage**

| | Pre-existing QMED ($m^3/s$) | FSU QMED with reduced BFI ($m^3/s$) | FSU QMED with URBEXT factor ($m^3/s$) | Change ($m^3/s$) | Change (%) |
|---|---|---|---|---|---|
| SC1 | 4.54 | 4.58 | 4.59 | 0.05 | 1.0% |
| SC2 | 2.51 | 2.58 | 2.60 | 0.09 | 3.6% |
| SC3 | 0.81 | 0.83 | 0.85 | 0.04 | 5.0% |
| SC4 | 1.54 | 1.56 | 1.56 | 0.02 | 1.3% |
| SC5 | 1.61 | 1.61 | 1.61 | 0.00 | 0.2% |
| SC6 | 3.49 | 3.49 | 3.50 | 0.01 | 0.3% |
| SC7 | 7.90 | 8.09 | 8.15 | 0.26 | 3.2% |
| SC7(a) | 3.93 | 3.95 | 3.99 | 0.06 | 1.5% |
| SC7(b) | 2.38 | 2.52 | 2.53 | 0.14 | 6.0% |
| SC7(c) | 2.87 | 2.97 | 3.00 | 0.13 | 4.4% |
| SC8 | 2.70 | 2.70 | 2.71 | 0.01 | 0.3% |
| SC9 | 5.79 | 5.80 | 5.80 | 0.01 | 0.2% |

**Table 15 Changes in FSU-calculated QMED due to urbanisation and constructed drainage**

## Estimated impacts of tree felling

The Slieve Aughty Mountains has some of the largest concentrations of coniferous forest plantation in the country, most of which was originally planted in the 1960s and 1970s.

The extent of forestry compartments has not changed appreciably since prior to project construction with forestry representing over 50% of land usage in the immediate vicinity of the wind farm. Due to its age profile, much of the forestry estate has over the last number of years and will over the next decade require felling. For example, between 2016 and 2018 a total of

2.57 km$^2$ of forestry was earmarked for felling on Coillte land in the catchments within which Derrybrien Wind Farm is located, similar to the amount felled for the wind farm Project between 2003 and 2005. It should be noted that for the purposes of this assessment, only the impact of felling associated with the wind farm project was considered and any other felling carried out in the area during construction and following commissioning is beyond the study scope.

Prior to the development of the wind farm, the site was a combination of turbary and Coillte forestry lands. The total area of forestry present on site following completion of the Project within the site boundary was 0.41 km$^2$ in 2009. This compares to 2.63 km$^2$ of forestry present on site in 2000, prior to construction. Therefore, the total area of forestry removed on site from 2000 onward to the end of construction was 2.22 km$^2$ (Figure 21). Table 16 summaries the area of trees removed in each subcatchment draining to the major rivers downstream off-site.

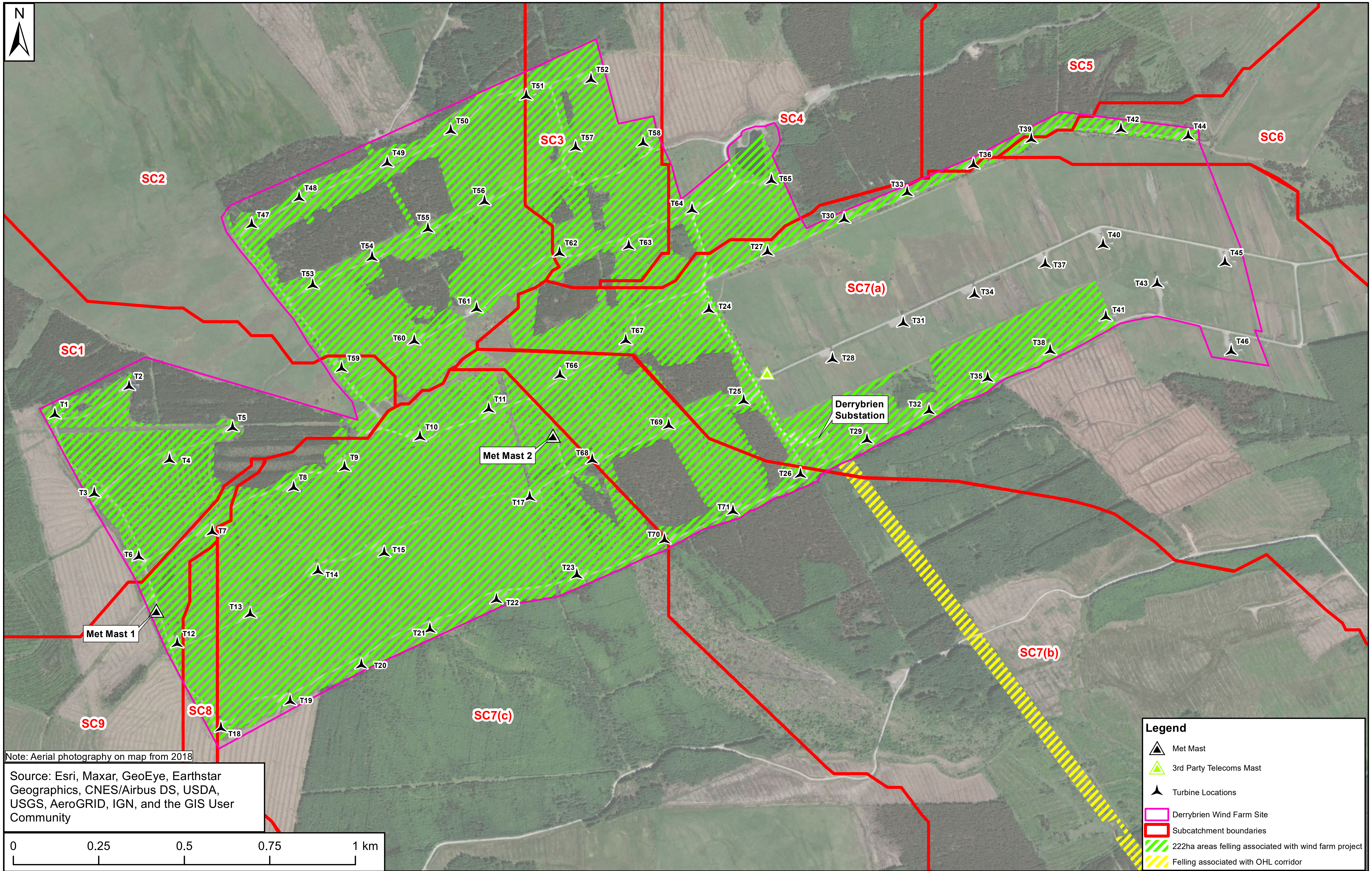
| Sub-catchment | Area (km$^2$) | On-Site Area (km$^2$) | Area felled on-site (km$^2$) | Area felled on OHL route (km$^2$) | Felled as a % of subcatchment area |
|---:|---:|---:|---:|---:|---:|
| SC1 | 6.44 | 0.31 | 0.18 | 0 | 2.86% |
| SC2 | 3.17 | 0.53 | 0.36 | 0 | 11.61% |
| SC3 | 0.96 | 0.22 | 0.20 | 0 | 20.73% |
| SC4 | 1.74 | 0.09 | 0.09 | 0 | 5.06% |
| SC5 | 2.22 | 0.01 | 0.01 | 0 | 0.41% |
| SC6 | 5.14 | 0.06 | 0.02 | 0 | 0.33% |
| SC7 | 13.04 | 2.13 | 1.26 | 0.20 | 11.20% |
| SC7(a) | 5.87 | 1.11 | 0.34 | 0.03 | 6.27% |
| SC7(b) | 3.02 | 0.23 | 0.18 | 0.12 | 9.85% |
| SC7(c) | 3.60 | 0.79 | 0.75 | 0 | 21.04% |
| SC7(d) | 0.61 | 0 | 0 | 0.05 | 8.20% |
| SC8 | 2.81 | 0.04 | 0.04 | 0 | 1.56% |
| SC9 | 6.48 | 0.05 | 0.05 | 0 | 0.71% |
| Agannygal | 2.00 | 0 | 0 | 0.04 | 2% |

**Table 16 Areas felled in subcatchments on wind farm site between 2000 and 2009**

The subcatchment which underwent the greatest amount of felling during wind farm construction was SC7 where 1.46 km$^2$ of forestry was felled on the wind farm site and OHL route, representing just over 11% of the total area of this subcatchment to the Owendalulleegh River and almost 60% of the subcatchment within the site boundary. In addition to this, 0.25 km$^2$ of forestry was removed by the landslide offsite in October 2003. However, unlike the forestry removed on the wind farm site, this area has since been gradually replaced by natural re-growth of forestry.

Unlike urbanisation, there is no well-established recommended approach to quantitatively assess the impacts of felling on downstream flow regimes, though there are a number of examples in the literature of peer-reviewed studies on the subject.

Through uptake of soil moisture from roots, evapo-transpiration and interception of rainfall, trees can reduce the soil moisture levels in the ground. In peatland areas, where groundwater would generally be considered as close to the ground surface, some depression of

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**Appendix 11A - Figure 21 - Areas felled associated with wind farm project**



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groundwater levels may be expected in areas under tree cover. Following tree removal, re-establishment of groundwater levels to post-tree planting levels would be expected with a resultant rise in the local groundwater level. In addition to this, there would be a relative increase in surface water runoff.

Consequently, most peer-reviewed scientific studies have generally found forests to be associated with reducing peak and low flows. However, despite multiple literature reviews investigating links between land use and river flows, the link between forests and river flooding remains conflicted (CEH, 2017). The UK's Centre for Ecology & Hydrology (CEH) report on this matter concluded that for decreasing tree cover, there is a significant difference between categories of influence on flood peak, arising largely as a result of the lack of recorded statements for peak flow increase. However, the number of observation-based statements reporting a flow increase due to decreasing cover was similar to the number reporting no influence, and it was not possible to reach a clear conclusion on this basis. The results for scenarios where there was a decrease in tree cover showed that for small events there was an increase in flood peak while for large events it was seen as having no influence.

Robinson et al. (2003) highlighted coniferous plantations on poorly drained soils in northwest Europe as among the situations where the most marked changes to flows are likely to occur. One particular study site was on an upland blanket bog in Co. Mayo similar to Derrybrien. It was noted that the lack of response to clear felling in some catchments may have been due to the limited change in the interception capacity between the standing forest and that of felled areas covered by large amounts of tree brash. Forest cutting generally leads to short-term increases in both peak flows and baseflows at the local scale, although this may not be detectable at the larger catchment scales. For all the forest types studied the changes to extreme flows will be diluted at the larger basin scale, where forest management is phased across a catchment. Overall, the results from the studies conducted under realistic forest management procedures have shown that the potential for forest clearance to increase peak and low flows is much less than has often been widely claimed.

A European Environment Agency (EEA) technical report on the water retention potential of forests in Europe concluded that in small sub-basins the water retention potential of forests was clear. This may be explained by the fact that the influence of forest cover on the runoff dynamics is easier to delineate and observe at smaller catchment scales. A simple statistical analysis indicated that a 10-15% decline in forest cover can increase the runoff. In general, with all other hydrological factors being equal, a catchment with 30% forest cover has a 25% higher water retention than an equivalent catchment with forest cover of 10%. Water retention is 50% higher in catchments with 70% forest cover than where forest cover is 10%.The OPW (2015) recommends, as an allowance in assessing flood risk, reduction in the time to peak to allow for potential accelerated runoff that may arise as a result of drainage of afforested land. For the MRFS and HRFS this amounts to a reduction by one-sixth and one-third respectively in the time to peak. Conversely, it is recommended to increase the runoff rate by a factor of 10% in the HEFS for the temporary period following felling of forestry (note no factor is recommended for the MRFS). This recommended runoff rate factor has been applied for this analysis.

As summarised in Table 16 the greatest changes in forest cover in any of the subcatchments encompassing Derrybrien wind farm were 21% reductions in SC3 and SC7(c). In subcatchment SC7 there was a 1.26 $km^2$ and 0.2 $km^2$ reductions in forest cover due to on-site and OHL route felling activities, amounting to just over 10% of the subcatchment to its confluence with the Owendalulleegh River. In all the other subcatchments less than 0.4 $km^2$ of forestry was felled. Considering increased hardstanding, additional drainage and forestry felling in combination the most affected subcatchment draining to a major river with respect to hydrology is SC7. According to the IH124 method (the more conservative estimate) there is a 4% increase in the mean annual maximum flow (QBAR). The 10% reduction in forestry conservatively is assumed to result in a 1% increase in runoff rates.

Combined, the Project is estimated to have resulted in a 0.27 $m^3/s$ increase in mean annual flood flow rates to the Boleyneendorrish compared to pre-Project flow rates. Note that if pre- and post-Project flow rates are scaled up to more extreme flow rates, the percentage increase in flow rates due to the Project will be the same. In the Owendalulleegh, the Project is estimated to have resulted in at most a 0.47 $m^3/s$ increase in mean annual flood flow to the Owendalulleegh (Table 17).

| Sub-catchment | Felled as a % of subcatchment area | Approx. change in flow rate due to felling % | Change in QBAR due to drainage (IH124, %) | Change in QBAR due to felling and drainage (%) | Change in QBAR due to felling and drainage ($m^3/s$) |
|---|---|---|---|---|---|
| SC1 | 2.86% | 0.3% | 1.2% | 1.4% | 0.06 |
| SC2 | 11.61% | 1.1% | 4.0% | 5.2% | 0.12 |
| SC3 | 20.73% | 2.1% | 5.7% | 7.8% | 0.06 |
| SC4 | 5.06% | 0.5% | 1.3% | 1.8% | 0.02 |
| Boleyneendorrish | | | | | 0.27 |
| SC5 | 0.41% | 0.0% | 0.1% | 0.2% | 0.00 |
| Duniry | | | | | 0.00 |
| SC6 | 0.33% | 0.0% | 0.3% | 0.3% | 0.01 |
| SC7 | 13.11% | 1.3% | 4.0% | 5.3% | 0.44 |
| SC7(a) | 6.27% | 0.6% | 0.9% | 1.5% | 0.06 |
| SC7(b) | 18.13% | 1.8% | 9.1% | 10.9% | 0.25 |
| SC7(c) | 21.04% | 2.1% | 5.4% | 7.5% | 0.19 |
| SC8 | 3.28% | 0.3% | 0.4% | 0.5% | 0.01 |
| SC9 | 1.56% | 0.2% | 0.2% | 0.3% | 0.01 |
| Owendalulleegh | | | | | 0.47 |

**Table 17 Summary of calculated change in QBAR due to wind farm Project**

***includes offsite forestry lost in landslide scar and on OHL Route**

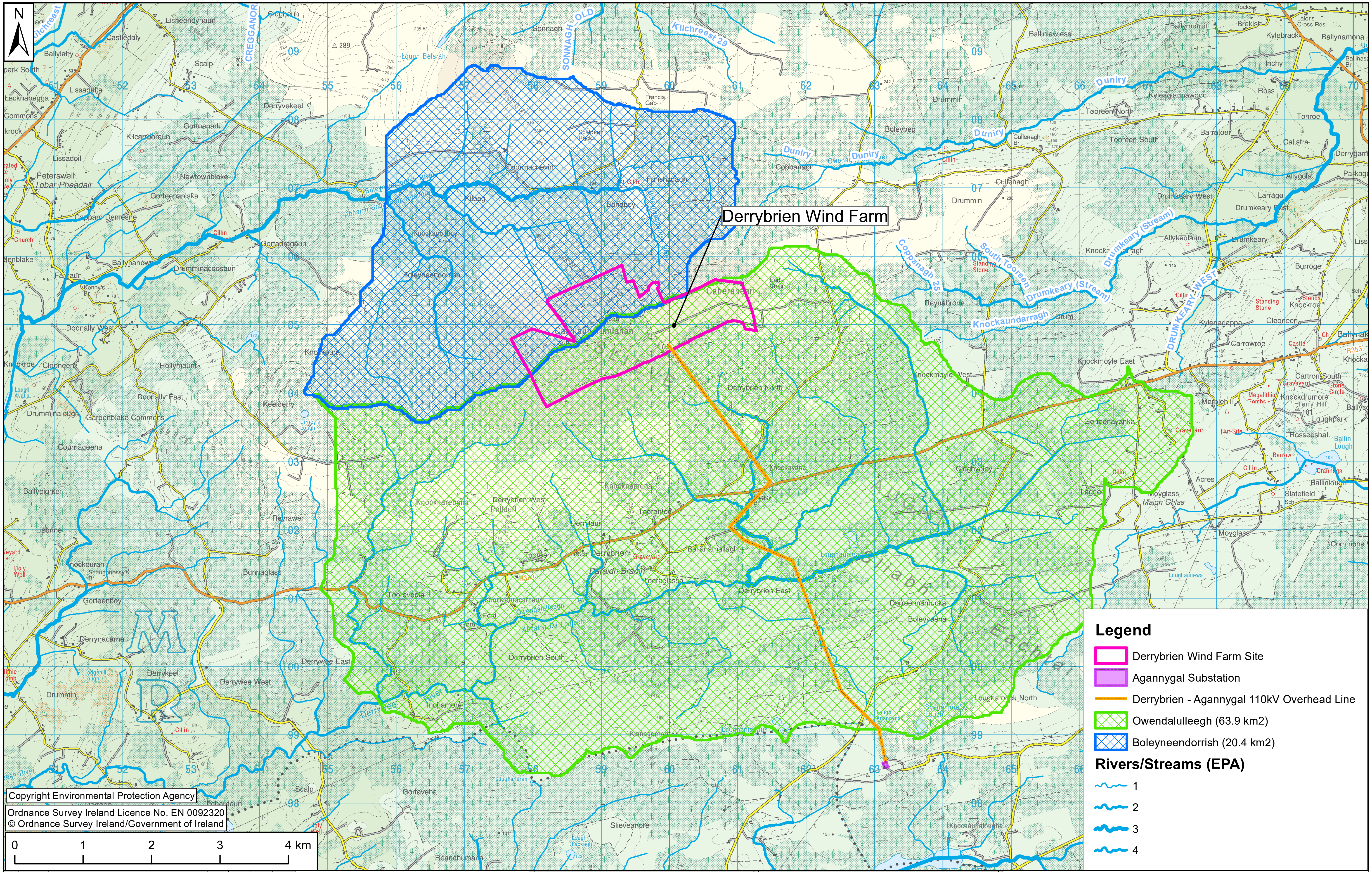
It should be noted that the time to peak in each of these subcatchments will vary depending on their individual physical characteristics. As well as this, the time at which the peak of each of these flows arrive at the same points of the main Owendalulleegh and Boleyneendorrish Rivers respectively will vary such that flood hydrographs will overlap at different points in time. The larger river catchments will thus have a longer time to peak (of the order of 6 to 12 hours) and effectively the increased QBAR figure will be attenuated rather than simply superpositioned. As such, summing the changes in QBAR as per Table 17 is a very conservative approach when looking at the broader scale impact of the wind farm Project.

Considering the Boleyneendorrish catchment in isolation, the total catchment area to where the relevant wind farm subcatchments (SC1 to SC4) meet this river is 20.4 $km^2$ (Figure 22) (EPA Ref: 29_595_1). The total area felled within this for the wind farm Project was 0.84 $km^2$. This represents 4% of the catchment area at this location. The FSU-calculated QMED at this point of the river system is 10 $m^3/s$ (corresponding to a QBAR of 10.7 $m^3/s$) while the IH124-calculated QBAR is 11.8 $m^3/s$. As such, by the most conservative estimate, the Project has resulted, in the most conservative analysis, in a 2.5% increase (0.27 $m^3/s$) in the peak mean annual flow rates at this scale.

At a broader scale, the areas that have been identified as having a recorded history of flooding downstream (Figure 4) lie to the west of the N66 national road 2 km downstream of where the Ballycahalan (formerly Boleyneendorrish) River meets the Streamstown River (EPA Ref: 29_190_4). The catchment area to this point is 62.8 $km^2$ (Figure 23). This area was identified by the OPW as being prone to turlough/groundwater flooding on an annual basis (ESBI, 2005). The felled area associated with the wind farm Project to this point in the catchment amounts to 1.3% of the total area. This represents 4% of the catchment area at this location. The FSU-calculated QMED at this point of the river system is 17 $m^3/s$ (corresponding to a QBAR of 18.2 $m^3/s$) while the IH124-calculated QBAR is much higher. As such, by the most conservative estimate, the Project has resulted in a 1.5% increase in the peak mean annual flow rates at this scale. Therefore, changes in flood peaks emanating from the wind farm Project can reasonably be expected to dissipate and not have any significant impact at larger catchment scales.

Considering the Owendalulleegh catchment in isolation, the total catchment area to where all the wind farm subcatchments (SC6 to SC9) meet this river is 64 $km^2$ (Figure 22) (EPA Ref: 29_136_2). The total area felled within this for the wind farm site was 1.37 $km^2$. Including the felled trees associated with the 2003 peat slide (0.25 $km^2$) and the construction of the OHL (0.31 $km^2$) in the catchment, this area increases to a total of 1.93 $km^2$. This represents 3% of the catchment area at this location. The FSU-calculated QMED at this point of the river system is 24 $m^3/s$ (corresponding to a QBAR of 25.7 $m^3/s$) while the IH124-calculated QBAR is 34 $m^3/s$. As such, by the most conservative estimate, the Project has resulted, in the most conservative analysis, a 1.8% increase in the peak mean annual flow rates at this scale.

At a broader scale, the areas identified as having a recorded history of flooding downstream (Figure 4) lie downstream of Lough Cutra on the Beagh River between Beagh and Gort (EPA Ref: 29_187_1). The catchment area to the outlet point of Lough Cutra totals 124 $km^2$ (Figure 23). The felled area associated with the wind farm site to this point in the catchment amounts to 1.6% of the total area. The FSU-calculated QMED at this point of the river system is 18.2 $m^3/s$ (corresponding to a QBAR of 19.5 $m^3/s$) while the IH124-calculated QBAR is higher. As such, by the most conservative estimate, the Project has resulted in a 2.4% increase in the peak mean annual flow rates at this scale. Note that Lough Cutra effectively attenuates flood peaks such that the predicted mean annual peak upstream of the lake is higher than it is downstream, despite it containing a smaller catchment. As with the Boleyneendorrish, any increased impact on downstream flood peaks from the wind farm Project can reasonably be expected to dissipate and not have any significant impact at larger catchment scales.

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DRAWING TITLE: Appendix 11A - Figure 22 - Extent of relevant catchments downstream of wind farm



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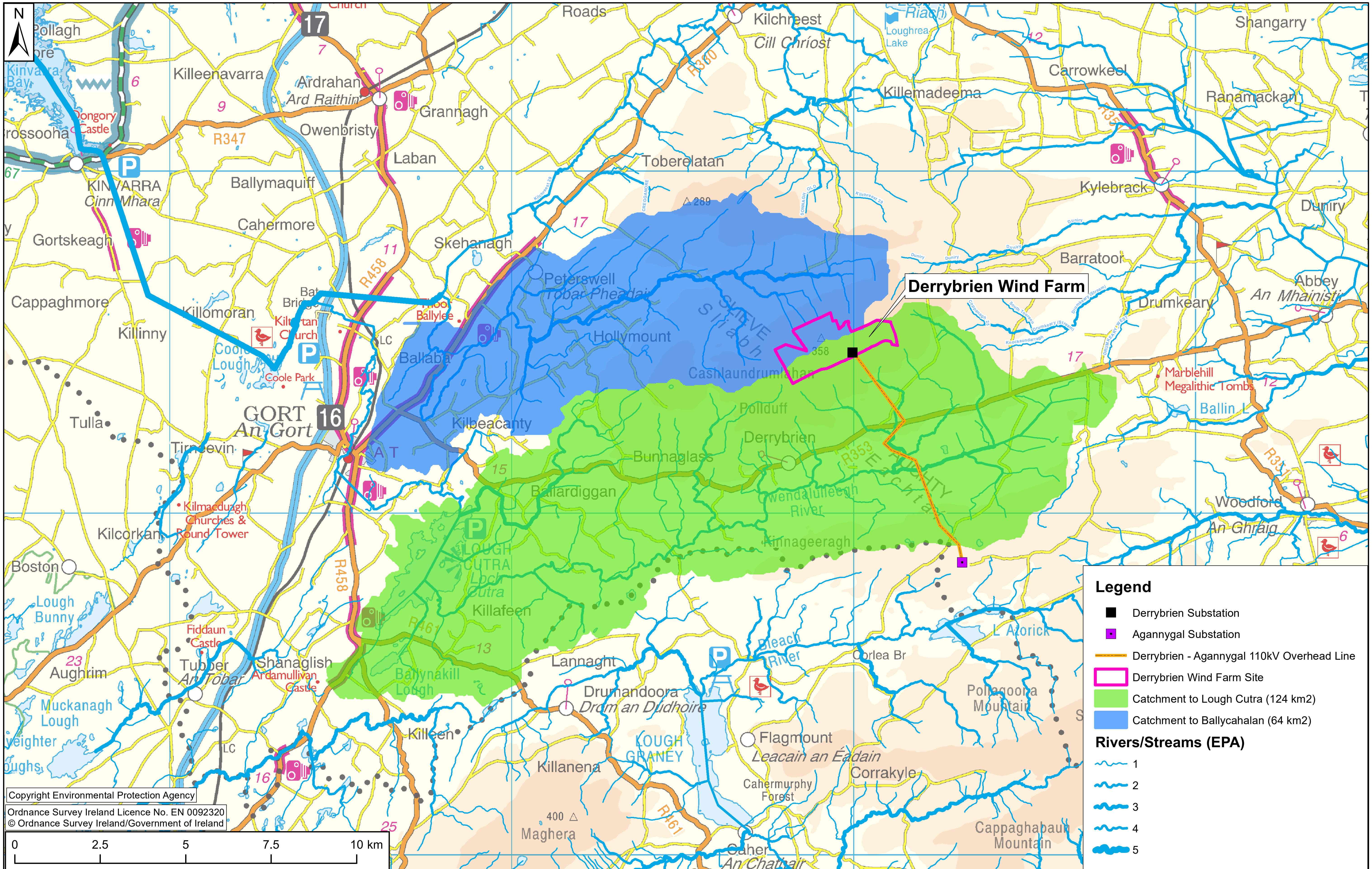


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**Appendix 11A - Figure 23**
**Extent of relevant catchments to flood-affected areas downstream of wind farm**



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It follows that the scale of the impact from the wind farm project in relation to the catchment to Kiltartan (302 $km^2$) where the two river catchments meet is small with felling accounting for less than 1% of the overall catchment area. For longer duration winter events of a number of days, the effect of the wind farm construction on peak runoff rates will be significantly curtailed and will be imperceptible downstream in the flood prone areas at Coole and Kiltartan which are more susceptible to longer duration flood events. This is discussed in more detail in Appendix 11.B.

Agannygal substation and a short southern section of the OHL corridor lies upstream of the Bleach River in a separate catchment to the remainder of the Project area (Figure 20). 0.04 $km^2$ of felling took place in this catchment to enable the construction. The size of the catchment from this site draining to Lough Atorick to the south is just under 2 $km^2$. As such 2% of this catchment area was felled to enable the construction.  All land downgradient to the south of the station access track is in Coillte ownership. As such there are no properties downstream within this area that could be adversely affected by the increased runoff rates associated with this change. It can therefore be concluded that the impact of the substation on the downstream flood regime is imperceptible.

# VII. Application of Justification Test

Box 5.1 of "The Planning System and Flood Risk Management – Guidelines for Planning Authorities" outlines the criteria required to complete the "Justification Test"; see Table 18.

Based on the results of the flood risk assessment for the wind farm, it is predicted that a portion of the site including that containing wind farm infrastructure may be liable to pluvial flooding during the 100-year and 1000-year mid-range future scenarios.

**Box 5.1 Justification Test for development management (to be submitted by the applicant)**

When considering proposals for development, which may be vulnerable to flooding, and that would generally be inappropriate as set out in Table 3.2, the following criteria must be satisfied:

1. The subject lands have been zoned or otherwise designated for the particular use or form of development in an operative development plan, which has been adopted or varied taking account of these Guidelines.
2. The proposal has been subject to an appropriate flood risk assessment that demonstrates:
   (i) The development proposed will not increase flood risk elsewhere and, if practicable, will reduce overall flood risk;
   (ii) The development proposal includes measures to minimise flood risk to people, property, the economy and the environment as far as reasonably possible;
   (iii) The development proposed includes measures to ensure that residual risks to the area and/or development can be managed to an acceptable level as regards the adequacy of existing flood protection measures or the design, implementation and funding of any future flood risk management measures and provisions for emergency services access; and
   (iv) The development proposed addresses the above in a manner that is also compatible with the achievement of wider planning objectives in relation to development of good urban design and vibrant and active streetscapes.

The acceptability or otherwise of levels of residual risk should be made with consideration of the type and foreseen use of the development and the local development context.

**Table 18 Justification Test for development management**

Referring to these Guidelines, the proposed development (classified as "highly vulnerable" in terms of its sensitivity to flooding) is appropriate for Flood Zone C. Therefore, the justification test needs to be applied.

Referring to Point 1 and Points 2 (i) to (iv) of the justification test in the Planning Guidelines on Flood Risk Management –

1. The subject lands have been designed for this form of development.
2. The development has been the subject of a flood risk assessment (this report) and this assessment has shown that:

i. Surface water arising within the site will be managed by the surface water management system designed and constructed for the wind farm project and which has been maintained as necessary since commissioning to protect wind farm infrastructure. As discussed in Section VI, the development has and will not increase the flood risk elsewhere and the overall flood risk;

ii. In relation to the continued operation and decommissioning of the wind farm, as per Section VI it is estimated that the drainage system in place does not exacerbate materially the downstream flood risk to people, property, the economy and the environment.;

iii. Regular maintenance has been carried out as necessary since commissioning of the wind farm. Drainage inspections are carried out monthly and following heavy rainfall or snow events. In addition to this, periodic geotechnical inspections have identified drainage maintenance issues which generally involve localised clearing out and maintaining sections of site drains. It is estimated based on experience over the previous 15 years of the wind farm life that access to the site for emergency services or essential maintenance will be possible during an extreme flood event. Residual pluvial flooding risk to the area has and will continue to be managed through the existing inspection and maintenance regime;

iv. The development is compatible with the wider planning objectives of the area.

As such, the wind farm as it is currently managed meets the criteria of the justification test.

# VIII. Loss of Floodplain

No element of the Project is located within a fluvial floodplain with the exception of a short section of the OHL Route which is a water-compatible element of the development.

# IX. Conclusions

The additional hardstanding area, new drainage and felling associated with the wind farm project were all considered in assessing and conservatively quantifying the effect of these factors on downstream flood risk. It is concluded that there was no significant increase in the risk of flooding arising from the wind farm Project in the locality of the wind farm itself given the size of the local downstream population and the proportion that could be affected in a flood event. On the broader regional scale, any increase in flood risk associated with the Project is deemed imperceptible given the broader extent of the Boleyneendorrish and Owendalulleegh catchments.

It can be concluded that most of the Project areas are not within floodplains and lie within Flood Zone C (Low risk of flooding) as defined by the guidance document to Planning Authorities in relation to Flood Risk Management. Furthermore, the existing flood risk in the downstream catchment has not to date and is not expected to be increased by any works over the operational life of the wind farm. Several elements of the wind farm infrastructure are vulnerable to pluvial flooding in extreme rainfall events. However, it is judged that the Project satisfies the criteria set out in the Justification as part of “The Planning System and Flood Risk Management – Guidelines for Planning Authorities”.

The Project as a whole is therefore considered to be in overall compliance with the objectives of the Planning and Flood Risk Management Guidelines. The Derrybrien Wind Farm Project therefore has not and is not anticipated to give rise to any significant impacts related to flood risk within or downstream of the Project areas.

# X. References

Bransby Williams, G. (1922). Flood discharge and the dimensions of spillways in India. The Engineer (London) 121: 321-322.

Cawley A.M. and Cunnane C., (2003) Comment on estimation of Greenfield runoff rates. Proceedings of UNESCO International Hydrological Programme, OPW.

Chow V.T., (1959) Open channel hydraulics, McGraw Hill, New York.

Centre for Ecology & Hydrology (2017) Do trees in UK-relevant river catchments influence fluvial flood peaks? A Systematic Review.

DEFRA (2008). Flood and Coastal Defence Project Appraisal Guidance. Supplementary Note to Operating Authorities. Assessing and Valuing the Risk to Life from Flooding for Use in Appraisal of Risk Management Measures. Department of Environment, Food and Rural Affairs.

ESBI (2005). OPW Flood Hazard Mapping – Phase 1. Meeting with Electoral Engineer for Loughrea. 10th May 2005.

European Environment Agency (2015) Water-retention potential of Europe's forests, A European overview to support natural water-retention measures.

Fitzgerald, D.L. (2007) Estimates of Point Rainfall Frequencies, Technical Note No. 61, Met Éireann, Dublin.

Flood Studies Report (FSR) (1975). National Environment Research Council.

French, R., Pilgrim, D. H. And Laurenson, E. M. (1974) Experimental examination of the rational method for small rural catchments. Civil Engineering Transactions CE16: 95-102.

Johnson R. (1998). The forest cycle and low river flows: a review of UK and international studies. Forest Ecol. Manag. 109: 1–7.

Marshall D.C.W. and Bayliss A.C. (1994) Flood Estimation for small catchments. IH Report no. 124. Institute of Hydrology.

Murphy, C. (2009). Flood Studies Update Work Package 2.3 – Flood Estimation in Ungauged Catchments. Final Report. June 2009.

NERC (1975). Flood Studies Report (5 volumes). National Environmental Research Council (Institute of Hydrology).

OPW (2009). The Planning System and Flood Risk Management – Guidelines for Planning Authorities. November 2009.

OPW (2012). Flood Studies Update (FSU) Programme WP4.2 Flood Estimation in Small and Urbanised Catchments. Work Package 4.2a. 30th January 2012.

OPW (2015). Climate Change Sectoral Adaptation Plan. Flood Risk Management (2015-2019). FRAM Section, Office of Public Works. May 2015.

Robinson, M. and Dupeyrat, A. (2005). Effects of commercial forest felling on streamflow regimes at Plynlimon. Hydrological Processes 19: 1213–1226.

Robinson M., et al. (2003). Studies of the impact of forests on peak flows and baseflows: a European perspective. Forest Ecol. Manag. 186: 85–97.

TII (2019). Drainage of Runoff from Natural Catchments. Volume 4 Section 2 Part 1. NRA HD 106/15. March 2015.

Xiao L., Robinson M., Rodgers M., O'Connor M., O'Driscoll C., Asam Z. (2011) Impact of Blanket Peat Forest Harvesting On Stream Flow Regime – A Case Study in the Burrishoole Catchment Co.

Derrybrien Wind Farm Project

Gort Windfarms Ltd.

# Remedial Environmental Impact Assessment Report

## Chapter 11 - Hydrology and Hydrogeology

## Appendix 11B – Flooding Assessment of the Derrybrien Wind Farm Project on Turlough Flooding in the Gort Lowlands Catchment

Document No.: QS-000280-01-R460-001-000

Date: July 2020

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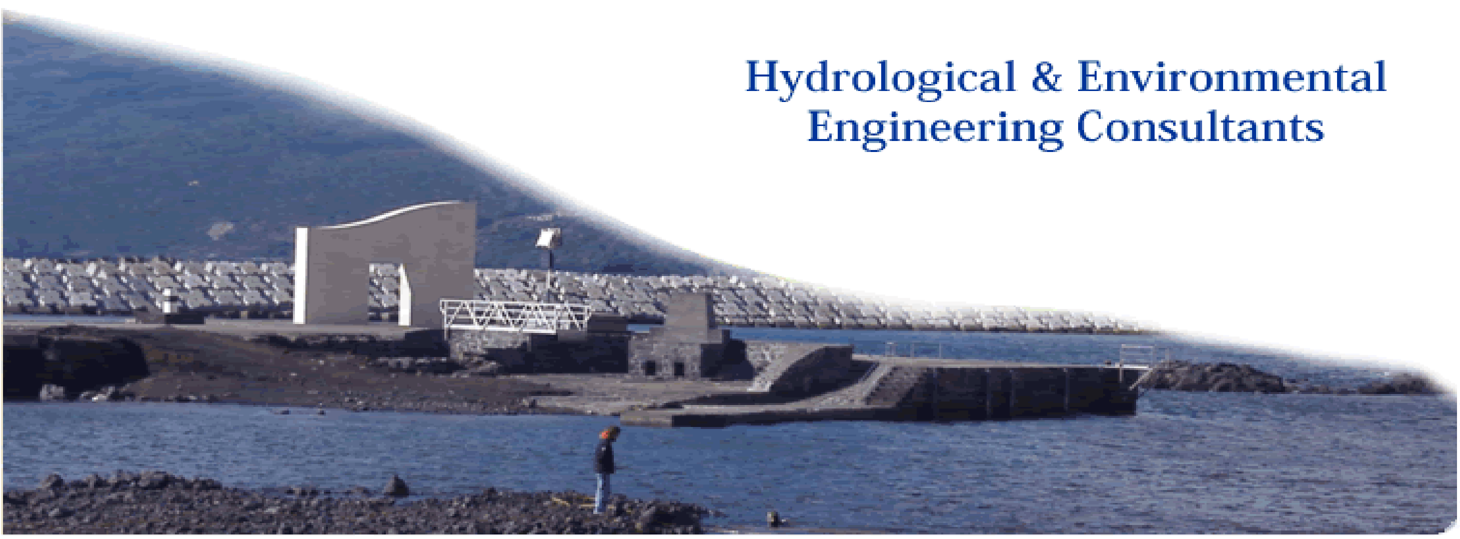
# Flooding Assessment of the Derrybrien Wind Farm Project on Turlough Flooding in the Gort Lowlands Catchment

**On behalf of**

**ESB**

**May 2020**



# Flooding Assessment of the Derrybrien Wind Farm Project on Turlough Flooding in the Gort Lowlands Catchment

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| Job No.: | 219001 |
| Report No.: | HEL219001v1.1 |
| Prepared by: | Anthony Cawley BE, M.EngSc, CEng MIEI |
| Date: | 14th May 2020 |

# TABLE OF CONTENTS

# 1. Introduction

The scope of this report is to examine the downstream flooding in the Gort lowlands area and the potential effect that the Derrybrien Wind Farm site has on this flooding. The overhead line route and Agannygal substation elements of the wind farm project are not considered in respect of downstream flood risk due to their respective areas and locations (see Appendix 11.A – Flood Risk Assessment).

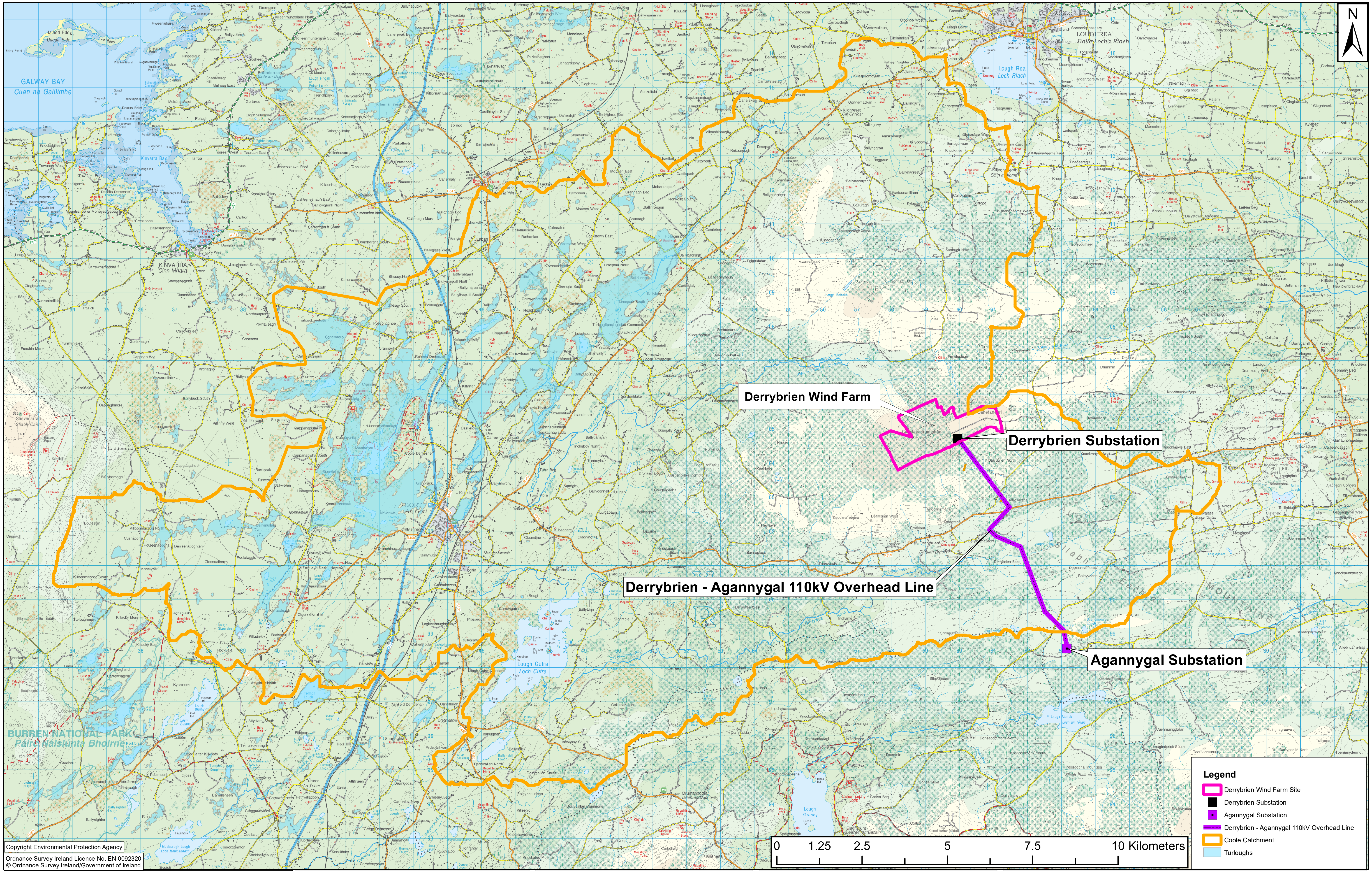
The Derrybrien Wind Farm site is located on the upper slopes of the Cashlaundrumlahan Mountain in Slieve Aughty mountain range in south County Galway. The total area of the Derrybrien Wind Farm site measures 3.44 km$^2$ (344 ha). The site and its drainage is located principally within two river systems – the Boleyneendorrish and Owendalulleegh catchments – which drain into the Gort lowlands area and eventually by groundwater flow out to sea at Kinvarra. A very small area of the Derrybrien site (< 1%), at the northeast corner of the site, drains to the Duniry River, a tributary of the Kilcrow River in the Shannon catchment. Approximately 66% of the site drains through surface drains SSW to the Owendalulleegh River and 33% of the site drains NNW into the Boleyneendorrish (Ballycahalan R.) River. This represents drainage areas of 2.3 km$^2$ and 1.1 km$^2$ in the Owendalulleegh and Boleyneendorrish river catchments respectively. These rivers discharge into the Gort lowlands area, which is prone to turlough flooding at times of prolonged heavy winter rainfall that lasts over a period of many weeks.

# 2. Regional Hydrogeology

## 2.1 General Description

The outlet from the Gort Lowlands catchment to the sea is underground via karst groundwater flow from swallow-holes in the pure limestones within turlough-forming basins of numerous turloughs in the Gort-Ardrahan area which includes some of the bigger turloughs of Blackrock, Ballylee, Kiltartan, Corker, Coole-Garryland, Caherglassaun and Cahermore. There is limited capacity in these underground conduit systems to discharge in flood conditions resulting in the groundwater table rising and the flooding out of turlough basins until they reach their natural threshold levels and spill overland, flowing from one turlough area to another.

The catchment extents of the Gort Lowlands to the Cahermore Turlough 4 km southeast of Kinvara Village is presented in Figure 1. Also shown for reference on this figure is the Geological Survey of Ireland (GSI, 2019) maximum historical groundwater flooding turlough flood extents and the 3.44 km$^2$ Derrybrien wind farm site in the Slieve Aughty Mountains to the east.



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DRAWING TITLE: Appendix 11B - Figure 1 - Catchment extents draining to the Coole – Garryland Turlough System



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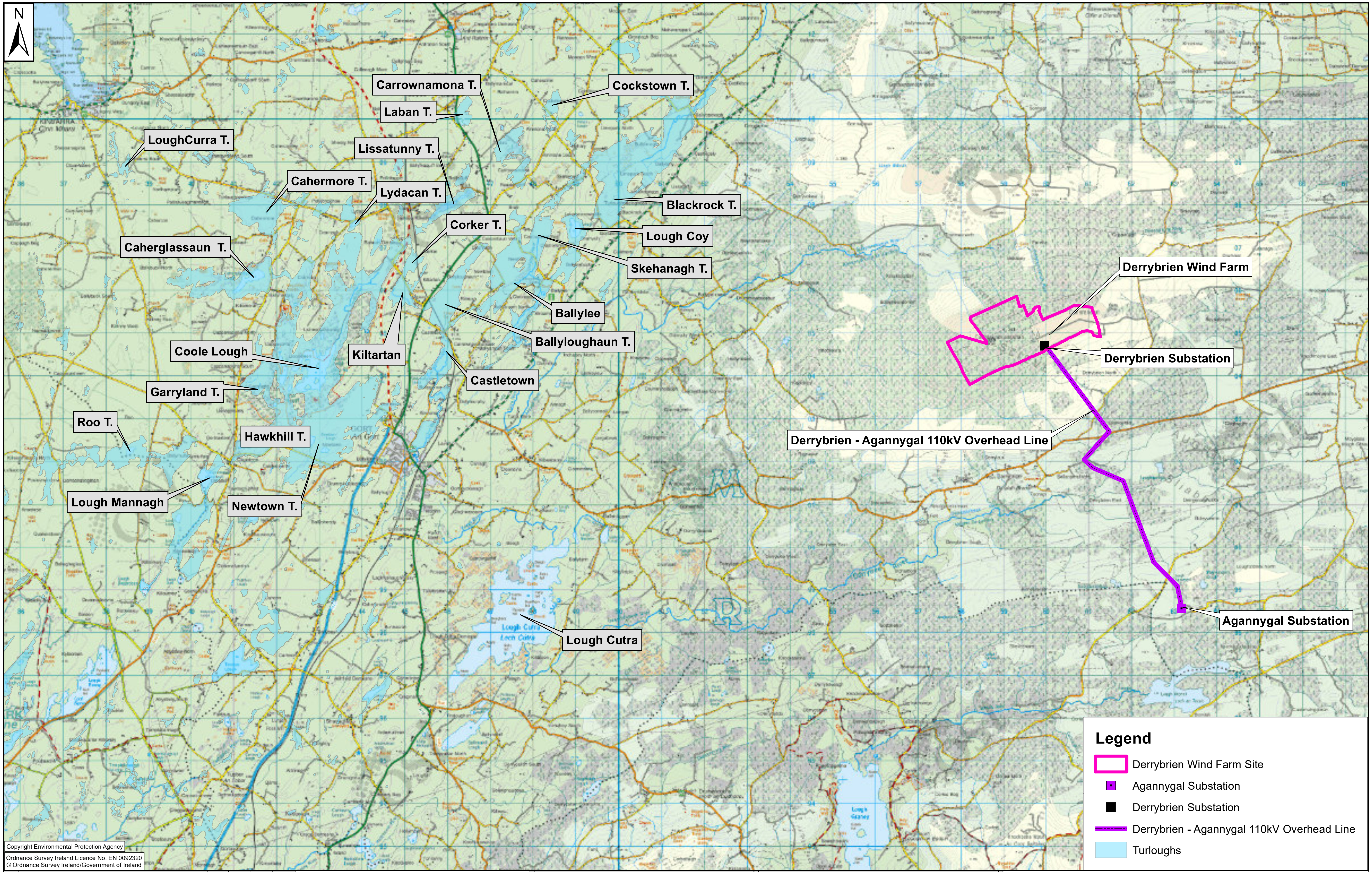
Groundwater and overland flow that enters the Coole and Garryland turlough system is stored until such time that it can discharge via its groundwater conduits. This can result in extensive overland flooding during large flood events when the groundwater outflow capacity is significantly exceeded. There are groundwater connections between, successively, Lough Coole and Caherglassaun and Cahermore turloughs and the Kinvarra springs where it enters the sea. The entire Kinvara catchment to Slieve Aughty potentially drains an area of 490 $km^2$.

A line running southwest from Kilchreest to Peterswell to Gort and south to the west of Lough Cutra represents the divide between Pure Limestone Bedrock formation to the west of this line and the impervious, muddy bedrocks that include conglomerates of Mudstone and Siltstone and Greywackes, Siltstones and Mudstones to the east. These conglomerates represent poorly productive bedrock aquifers and are overlaid by peats and silts having very low groundwater recharge rates of less than 10%. The pure limestone formations with a free draining limestone till have groundwater recharge rates of c. 60% and the limestone outcrop areas have recharge rates of c. 85%. There is a contrasting picture in the density of surface drainage features between east and west of the overall catchment with a high density of surface drainage features in the muddy impervious bedrock areas and a near absence of surface drainage features in the highly karstified pure limestone formations to the west.

The pure limestones in the Gort Lowlands area to Kinvara are highly karstified and there are no surface flow outlets to the sea, with drainage outflow from the area entirely via groundwater flow in large conduits and caverns. Significant dye tracing of the Gort Lowlands karst system has been conducted by David Drew, Trinity College, GSI and the Gort Lowlands Flood Study (Drew and Daly 1993, Southern Global Water 1997 and GSI 2020) and this shows a wide spread of groundwater flow linkages between turloughs and inland and coastal springs at Kinvara surrounding coastal areas. The Gort Lowlands system is completely dependent on groundwater flow for outflow. There are no watercourse channels present to convey runoff to the coast. Turloughs begin to fill with the rising regional groundwater table and fill further when the inflow to the turlough exceeds its outflow capacity.

The many large turloughs in the Gort Lowlands system are presented in Figure 2. The flooding of these turloughs is influenced by the inflow but also by downstream flood conditions in the interconnected turloughs and in extreme winter flooding events such as 2009 and 2015/2016 these turloughs rose significantly resulting in overland spills between turloughs in a cascade-like manner.



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**Appendix 11B - Figure 2**
**Main Turlough Flooding areas in the Gort Lowlands area**
**(2009 groundwater flood extents)**



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# 3. Regional Hydrology

## 3.1 General Description

The basin area lying between the Dunkellin catchment to the north and the River Fergus Catchment to the south is referred to as the Gort Lowlands catchment. There is no direct river outlet to the sea and drainage from the 500 $km^2$ catchment area must discharge in underground conduits and caverns within the karst limestone bedrock to Galway Bay. The long term annual average rainfall for the Gort Lowlands Catchment is measured to be 1140 mm (from the most recent Met Eireann (2020) Standard Annualised Average Rainfall (SAAR) map). The expected annual average groundwater flow rate discharging to the sea from this catchment is approximately 10 $m^3/s$ based on an annual average evapotranspiration rate of 510 mm. The median annual maximum flow rate from this catchment is likely to be c. 50 $m^3/s$ and the 100 year flow based on a national flood growth curve factor of 2 is c. 100 $m^3/s$.

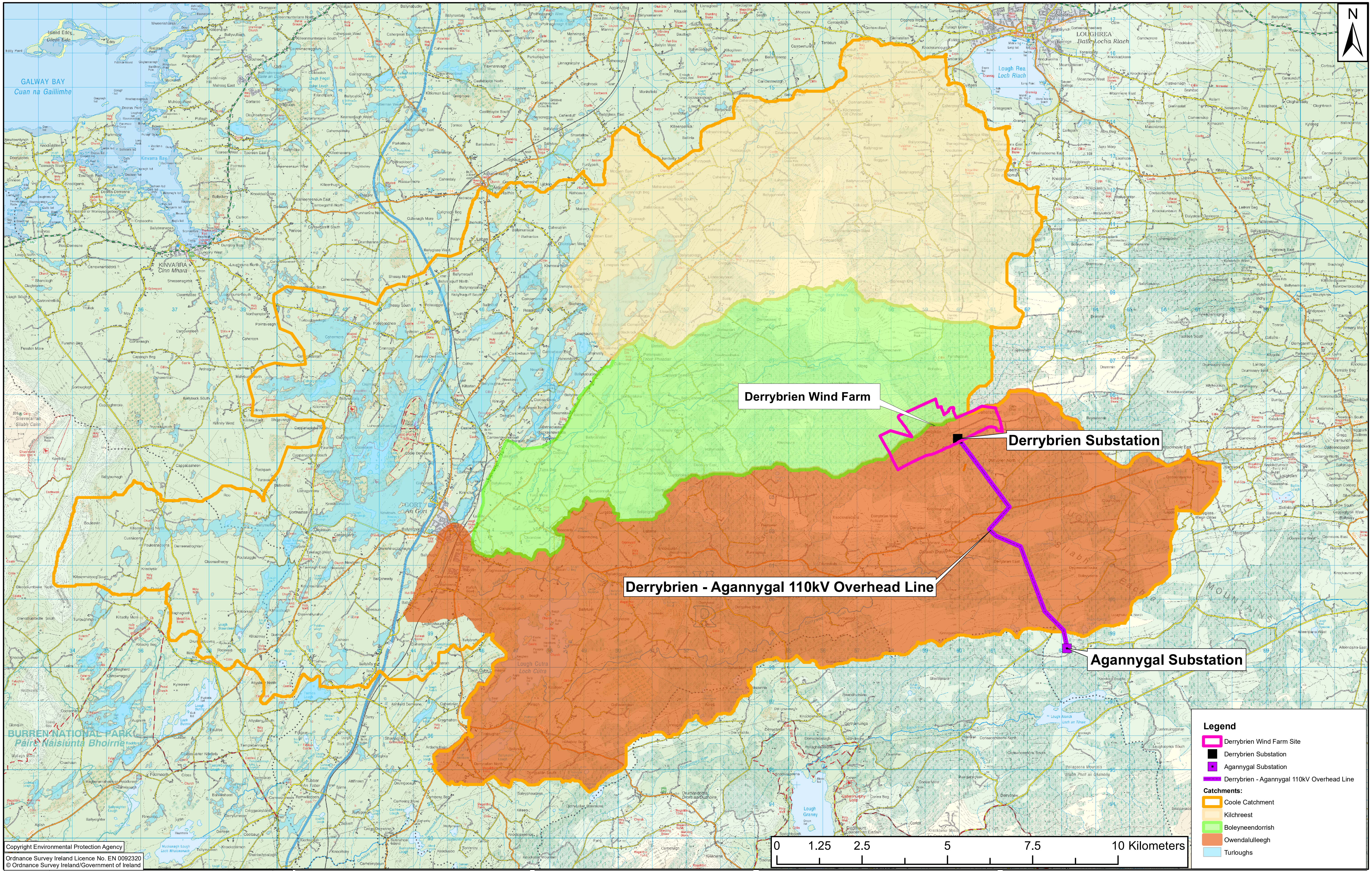
The total drainage catchment to Kinvara sea outlets can be split between the impermeable catchment area to the east, of some 240 $km^2$ in area that is underlain by muddy limestones, old sandstones, shales, mudstone and siltstone conglomerates and having generally low groundwater recharge rates and conversely naturally high runoff coefficients. The catchment area to the west is underlaid by permeable pure limestones having an area of a further 260 $km^2$ with moderate to high groundwater recharge rates. What is noticeable between east and west is the high density of stream and drainage channels in the east with the very sparse surface drainage features in the pure limestones. Higher annual rainfalls occur in the more elevated lands to the east with the highest annual rainfalls occurring in the Slieve Aughty uplands at on average 1430 mm per annum whereas in the lowlands area the annual rainfall is typically 1125 to 1175 mm per annum.

## 3.2 Contributing upland Catchments

Three main upland rivers drain westwards into the Gort Lowlands area off the relatively impervious eastern section of the catchment which includes the Slieve Aughty uplands. These rivers from south to north are:

- the Owendalulleegh River that inflows to Lough Cutra and on to Gort Town as the Beagh / Cannahowna / Gort Rivers;
- the Boleyneendorrish (Ballycahalan) River to Ballylee; and
- the Owenshree River that discharges into Blackrock Turlough which overflows to Ballylee.

Refer to Figure 3 for catchment extents of these rivers.

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PROJECT: Derrybrien Wind Farm Project

CONTRACT:

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DRAWING TITLE: Appendix 11B - Figure 3 - River catchments discharging to the Gort-Lowlands



| DRAWN | PRODUCED | VERIFIED | APPROVED | APPROVAL DATE |
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### 3.2.1 Owendalulleegh Catchment

The Owendalulleegh River rises in the townland of Gorteenayanka and flows westward to Lough Cutra. The catchment area of the Owendalulleegh River to Lough Cutra is 90 $km^2$ and to the Lough Cutra outflow (Beagh River) is 124 $km^2$ and to Gort Town (Gort River) is 134.6 $km^2$. Lough Cutra is a large lake with a permanent surface area of 3.8 $km^2$ which increases to c. 4.4 $km^2$ in flood. Typical lake levels are 32.9 mOD Malin and the typical summer-winter lake level range is 1.2 m (EPA hydronet resource). This lake provides some attenuation to the Owendalulleegh River flood inflow and, as a result, to a certain extent protects downstream reaches through Gort Town. The outflow (Beagh River) from Lough Cutra sinks underground at the Punch Bowl 2 km downstream of the lake and re-emerges as the Gort River at the Pollduagh Cave, south of Gort, and flows northwards through Gort Town before sinking again at the Castletown Swallow-holes (3 km north of Gort). There is a groundwater connection between the Castletown Swallow-holes and the Kiltartan risings. During large floods an overland flood route exists at Castletown, discharging northwards to Ballyloughan and Kiltartan floodplains before entering the Lough Coole and Garryland Turlough system. The time to peak ($t_p$) for flood runoff to reach the inlet to Lough Cutra from the Owendalulleegh catchment is estimated to be 8 hours. The estimated median flood peak rate just upstream of Lough Cutra is 30.5 $m^3/s$ from the Flood Studies Update (FSU) flood estimation method and the critical rain storm duration for peak catchment runoff is 19 hours, which represents a reasonably flashy catchment that produces maximum flood rates during 1-day events. The maximum outflow rate and critical rain storm duration depends on the level the lake is and can typically delay the peak by between 12 to 24 hours.

### 3.2.2 Boleyneendorrish Catchment

The Boleyneendorrish (Ballycahalan) River which has its headwaters in the Slieve Aughty upland, conveys runoff in a westerly direction towards the N66 (Loughrea Road). Downstream (west) of the N66 it becomes the Streamstown River and the Turra River inflows to it before flowing northwards to Ballylee where it sinks at the Ballylee swallow holes. The total catchment area of this river to the Ballylee sinks is 61 $km^2$. Two large turloughs, Skehanagh and Newhall, form to the north and northeast of Ballylee. During extreme floods these turloughs become one and the entire Ballylee area floods out. There is an overland flood route from Ballylee floodplain to Ballyloughaun Floodplain to the east of Kiltartan. The estimated catchment area to Ballyloughaun is c. 152 $km^2$, which also includes the Owenshree catchment . There is a groundwater connection between the sinks at Ballylee and the Kiltartan Springs. Downstream of Kiltartan the flow sinks underground and enters the Coole-Garryland Turlough. At times of large floods an important overland flow route is available from Kiltartan via the Corker Turlough and under the M18 at Raheen / Kilkelly to the Coole-Garryland Turlough. The time to peak for flood runoff in the Boleyneendorrish catchment to reach the Streamstown Section at Thoor, Ballylee is 6 hours based on the Flood Study Report time to peak method using catchment characteristics (NERC, 1997, Cawley and Cunnane, 2003). The median flood peak rate is 16 $m^3/s$ using the FSU method. Similarly to the Owendalulleegh catchment this represents a relatively flashy catchment.

### 3.2.3 Owenshree / Kilcreest Catchment

The Owenshree River has its headwaters in the northern extremity of the Slieve Aughty upland and flows south-westwards before terminating at the Blackrock Sinkhole near Peterswell. The Blackrock turlough swallow hole system is understood to drain to Lough Coy and the Polleelin / Pollanoween system at Ballylee. At times of large floods an overland flow path from Blackrock Turlough through to Skehanagh village towards Skehanagh Turlough and Ballylee becomes established. The catchment area of the Owenshree River to Blackrock Swallow-holes is 78.5 $km^2$. The time to peak for flood runoff to reach the Blackrock Turlough Swallow hole is estimated to be 7.5 hours. The estimated annual median flow rate in the upstream catchment to Blackrock Turlough is 16.35 $m^3/s$ using the FSU flood estimation method.

### 3.2.4 Kiltartan Floodplain

The catchment area to Kiltartan Springs includes all of the above three river catchments and the local turlough basins and surrounding lands, which based on surface topography is c. 301 $km^2$ in area. It should be noted that the karst groundwater conduit flow system in the Gort Lowlands is complicated and has multiple connections between various sinks and springs with some groundwater connections bypassing the springs at Kiltartan and discharging directly to other turloughs and to the coastal springs near Kinvara (GSI, 2020). The flow rising from the springs at Kiltartan and its overland component discharges into the Coole-Garryland via swallow holes and an overland flow route via Corker and Raheen. Past flood events have caused extensive flooding at Kiltartan with houses, roads (including the former N18) and the church at Kiltartan flooded.

### 3.2.5 Lough Cutra

The EPA-gauged outflow from Lough Cutra gives a median flood (2-year return period) peak outflow rate of 19.15 $m^3/s$ whereas the median flood inflow rate is 30.5 $m^3/s$ . This suggests that Lough Cutra attenuates the flood peak by c. 30% for the median annual flood. The historical highest flooding recorded for Lough Cutra, since the gauge record began in 1976, occurred on 19$^{th}$ – 20th November 2009. In a 48 hour period from 4:00am on the 18$^{th}$ November to 4:00am on the 20$^{th}$, the lake level rose by 0.86 m to 34.67 mOD representing a flood storage volume of approximately 3.44 million $m^3$ based on a lake surface area of 4 $km^2$. To fill such a volume in a 48 hour period requires an inflow rate to be on average 20 $m^3/s$ in excess of the outflow rate during that period. The gauged peak outflow from Lough Cutra gives a flow rate estimate of 55.6 $m^3/s$ suggesting a peak inflow rate in excess of 75 $m^3/s$. The estimated peak outflow from Lough Cutra using the EPA rating curve involves considerable extrapolation beyond the gauged range of flows and is likely to be significantly overestimated being backwatered from downstream by the flow capacity of the Punch Bowl Swallow-holes. It is more likely that the peak inflow and outflow were c. 60 and 40 $m^3/s$ respectively. The flooding of the lands surrounding the downstream reach from Lough Cutra is caused by the throttle effect from the Punch Bowl swallow-hole and by the hydraulic capacity of the Beagh River outflow channel. In 2009 the lake effectively delayed the flood peak by almost 24 hours between the peak inflow and outflow.

## 3.3 Land use

The general land use cover in the Gort Lowlands catchment and its 3 no. upland catchments is summarised below in Tables 1 to 4 and also shown in Figure 4. This land-use mapping is based on the latest available Corine land-use mapping (2018). This shows that forestry and wetlands / bogs make up a significant portion of the land use in these catchments at c. 46% for the overall Coole catchment of 388 km$^2$ and slightly over 50% is grassland / pasture. In the upland catchments of the Boleyneendorrish and Owendalulleegh River systems, forestry and peatlands represent 60 to 67% of the land use; refer to Tables 3 and 4.

The Boleyneendorrish and Owendalulleegh catchments have significant fraction of their catchments associated with forestry at 41 and 50% respectively.

**Table 1 Corine Landcover for the overall Coole Catchment**

| Class Description | Area (Ha) | Area (km$^2$) | Area (%) |
|---|---|---|---|
| Artificial surfaces | 190.64 | 1.96 | 0.50% |
| Agricultural areas (grassland and pastures) | 20155.50 | 201.56 | 51.90% |
| Forest and seminatural areas | 12810.15 | 128.10 | 33.00% |
| Wetlands & Peat bogs | 4982.23 | 49.82 | 12.80% |
| Water bodies | 668.51 | 6.69 | 1.70% |

**Table 2 Corine Landcover for the Owenshree (Kilchreest) Catchment**

| Class Description | Area (Ha) | Area (km$^2$) | Area (%) |
|---|---|---|---|
| Artificial surfaces | 0.045 | 0 | 0.00% |
| Agricultural areas (grassland and pastures) | 5313.75 | 53.14 | 67.50% |
| Forest and seminatural areas | 1519.40 | 15.19 | 19.30% |
| Wetlands & Peat bogs | 1040.33 | 10.40 | 13.20% |
| Water bodies | | | |

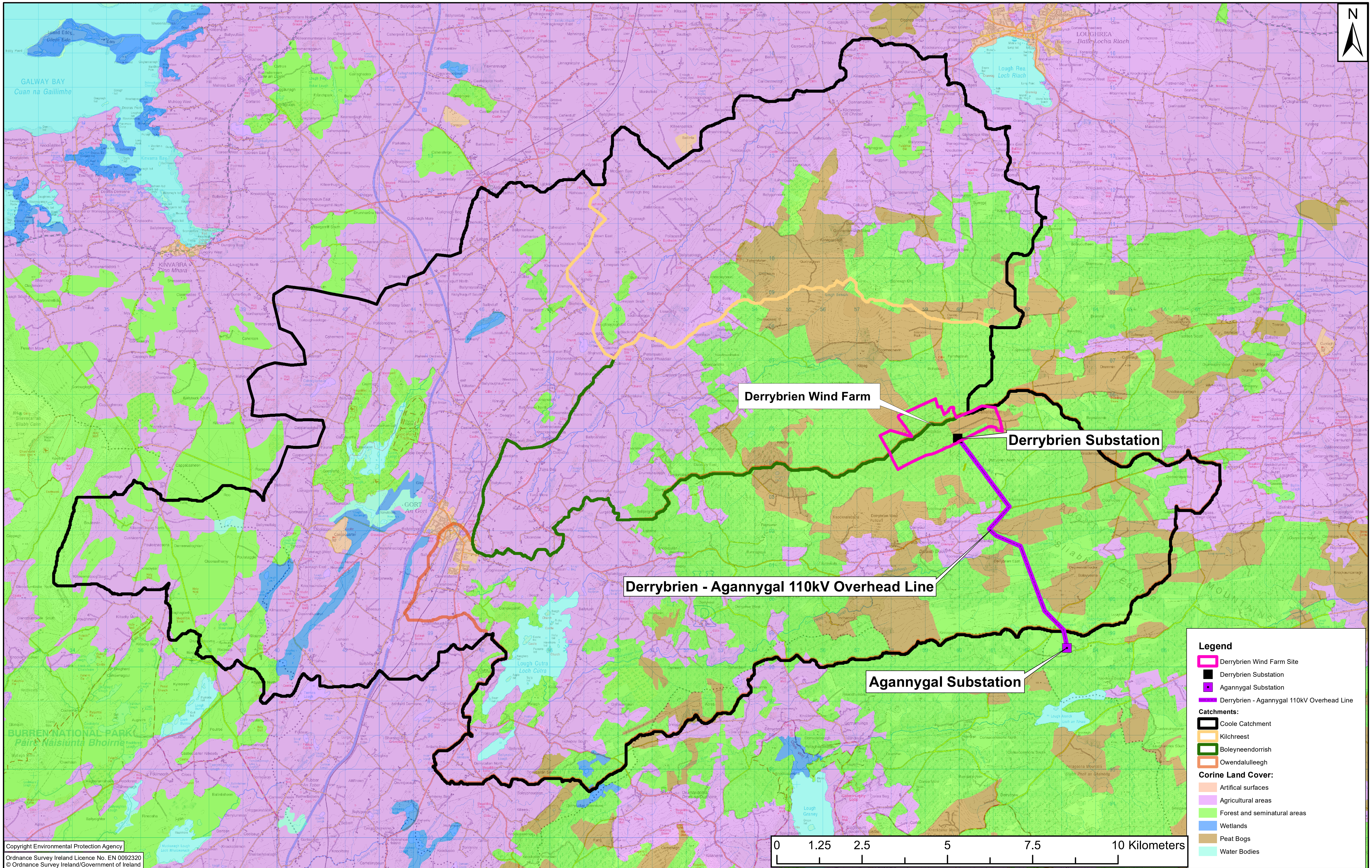
**Table 3 Corine Landcover for the Boleyneendorrish Catchment**

| Class Description | Area (Ha) | Area (km$^2$) | Area (%) |
|---|---|---|---|
| Artificial surfaces | 3.31 | 0.03 | 0.10% |

| | | | |
|---|---|---|---|
| Agricultural areas (grassland and pastures) | 2424.00 | 24.24 | 39.50% |
| Forest and seminatural areas | 2521.71 | 25.22 | 41.10% |
| Wetlands & Peat bogs | 1179.96 | 11.80 | 19.20% |
| Water bodies | | | |

**Table 4 Corine Landcover for the Owendalulleegh Catchment**

| Class Description | Area (Ha) | Area ($km^2$) | Area (%) |
|---|---|---|---|
| Artificial surfaces | 83.81 | 0.84 | 0.62% |
| Agricultural areas (grassland and pastures) | 3978.43 | 39.70 | 29.46% |
| Forest and seminatural areas | 6703.61 | 67.04 | 49.64% |
| Wetlands & Peat bogs | 2317.72 | 23.18 | 17.16% |
| Water bodies | 421.75 | 4.22 | 3.10% |

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DRAWING TITLE: Appendix 11B - Figure 4 - Corine Landuse Classes



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# 4. Flooding

## 4.1 Historical Flooding

Severe turlough flooding in the Gort Lowlands system is associated with heavy prolonged winter rainfall events over many weeks and generally associated with sustained heavy rainfall between December and February (except for 2009 when extreme rainfall in November produced peak levels towards the end of November and early December).

Historically severe turlough flooding in the Gort Lowlands area occurred in

- 1989/1990
- 1993/1994
- 1994/1995
- 1999/2000
- 2009
- 2015/2016
- February-March 2020

**Plate 1 Recent flooding in the Kiltartan Area on 26th February 2020**

The most extensive flooding occurred in the Coole-Garryland Turlough in 2015/2016 (with the peak occurring in early January 2016). This event was followed in severity by the Nov/Dec 2009 flood (rainfall primarily fell in late October and November 2009) and the third ranked flood was the 1994/1995 flood that peaked at the end of January and early February1995. All flooding in the Gort Lowlands turloughs is winter-dominated flooding produced by prolonged rainfall events over many weeks as opposed to short duration flooding events over hours and days. The most recent event that peaked at the end of February / early March 2020 is ranked in terms of severity as the fourth worst event behind 2015/16, 2009 and 1994/95 events.

The observed peak flood levels in 2009 and 1994/1995 were similar at Blackrock and Thoor Ballylee Tower, but the 2009 flooding progressively exceeded 1994/95 in down-gradient turloughs, with flood levels in Caherglassaun approximately 0.7 m higher in 2009. A comparison between 2009 and 2015/2016 showed that flood levels were higher in 2009 at Blackrock by c. 0.3 m but were surpassed by the 2015/16 event in the downstream turloughs at Kiltartan and Corker, Coole-Garryland, Caherglassaun and Cahermore Turloughs due to the greater volume and longer duration of the flooding event. In 2015/2016 the peak flood levels surpassed the 2009 event in the Caherglassaun Turlough by c. 0.8m and at Cahermore by over 1 m. Table 5 below presents estimated historical maximum flood levels at the various Gort Lowlands turloughs.

**Table 5 Historical maximum flood levels in a number of the turlough areas**

| Location | Maximum Flood Level m | Year |
|---|---|---|
| Blackrock Turlough | 29.45<br>(29.15) | 2009<br>(2015/16) |
| Lough Coy | 19.3<br>(19.15) | 2009<br>(2015/16) |
| Ballylee floodplain and Swallow hole area | 19.15 to 19.4 | 2015/2016 and 2009 |
| Ballyloughaun and lower Castletown Floodplains | 18.0 to 18.2<br>(<16.5) ** | 2009<br>(2015/2016) |
| Kiltartan | 14.9 – 15.2<br>(14.9 at Kiltartan Church) | 2015/2016<br>(2009) |
| Coole Lough (Garyland) | 14.65<br>(13.7) | 2015/2016<br>(2009) |
| Hawkhill (Coole) | 14.63<br>(13.75)<br>(13.3) | 2015/2016<br>(2009)<br>(1994/1995) |
| Caherglassaun | 14.5<br>(13.8) | 2015/2016<br>(2009) |
| Cahermore | 13.4<br>(12.5) | 2015/2016<br>(94/95 and 2009) |

** the flooding at Ballyloughaun floodplain in 2015/2016 was significantly reduced due to the replacement of undersized culverts beneath the former N18 road near Kiltartan, otherwise it would have been expected to be similar to 2009 max flood levels which had then spilt over the road.

A review of long-term rainfall records in the earlier Gort Lowlands Flooding Study (SGW/JOD, 1997) concluded that in the 50 years preceding the first notable flood event in 1989/1990 that the prolonged rainfall events recorded, except for 1959, were not sufficient in rainfall amount to have produced severe turlough flooding in the Gort Lowlands compared to the more recent listed significant events in Section 4.1 above.

A review of the daily rainfall records from the Derrybrien II rain gauge (at altitude of 155 mOD) for the available record period 1982 to 2019 showed the following amounts in respect to the historical events:

- In 89/90 586 mm of rainfall fell in 3 months, namely December ' 89, January '90, February '90 having an average rate of 6.51 mm/day.
- In 93/94 646 mm of rainfall fell in a 3-month period from the 27th Nov 94 to 26th Feb 95 producing an average rate of 7.18 mm/day.
- In 94/95 820 mm of rainfall fell in 101 days from 2nd Dec 1994 to 10th Mar 1995 producing an average daily rate of 8.12 mm/day and this event followed a moderately wet November having a monthly total of 121 mm.
- In 99/00 631 mm rainfall fell in 102 days representing an average daily rate of 6.19 mm/day.
- In 2009 following a wet July (190 mm) and August (191 mm), a moderately dry September (58 mm) and a wet October (139.3 mm) 469 mm fell in a 29-day period from 30 October to 27 November producing an average daily rate of 16.2 mm/day.
- In 2015/16, similarly to 2009, a wet summer with 111 mm in July and 122 mm in August followed by moderate rainfall amounts in September and October of 75 mm and 66.6 mm respectively was followed by 708 mm from 4th Nov to 7th January (10.9 mm/day).
- In 2020 a record wet month in February recorded over three times its monthly average with the bulk of the rain falling in a 24 day period with an average in excess of 10 mm per day over the month of February.

Derrybrien II is a point measurement at an altitude of c. 155 mOD and does not necessarily reflect the actual catchment-wide rainfall amounts as the lower altitudes within the Owendalulleegh catchment are likely to have had lower rainfall amounts, but the rainfall pattern from Derrybrien does represent very well the prolonged nature of the rainfall that produces the significant downstream flooding in the Gort Lowlands turloughs. Figure 5 presents the location of the rain gauge network in the North Clare / South Galway area. There is not a complete record at all of these stations for the period of floods from 1989 onwards but a review of the available daily record shows similar trends to the Derrybrien rain gauge.

The flood extents for the Gort Lowlands turloughs associated with the 2009 flood event that has been produced by the GSI is shown in Figure 2. The total surface area of turlough flood inundation in 2009 was 20.75 $km^2$. Based on these flood extents a 10 cm rise in flood level represents c. 2 million $m^3$ of flood storage which in terms of the contributing catchment area of 338 $km^2$ represents a rainfall depth of 5 mm. It should be noted that all the flood events listed above the prolonged rainfall depths over one or two months were well in excess of 5 mm/day. At a certain rainfall rate the groundwater outflow capacity of the turloughs (this will vary from turlough to turlough) is surpassed and the excess rainfall must store and eventually flood and spill overland. Essentially the turlough flooding in the lowlands area surrounding Coole, Kiltartan and Ballylee is dominated by the flood volume entering over a prolonged period as opposed to high intensity short duration inflows that would be more critical to flooding in the more upland valley sections of the catchment to the east and northeast of the Gort Lowlands area.

The 2015/2016 flood extents have been produced by Ryan Hanley Consulting Engineers for the Gort Lowlands Flood Relief scheme but is currently in draft form and is not published. A paper by Naughton and McCormack (2016) of the GSI presented the flood extents for the winter 2015/2016 event, refer to Plate 2 below.

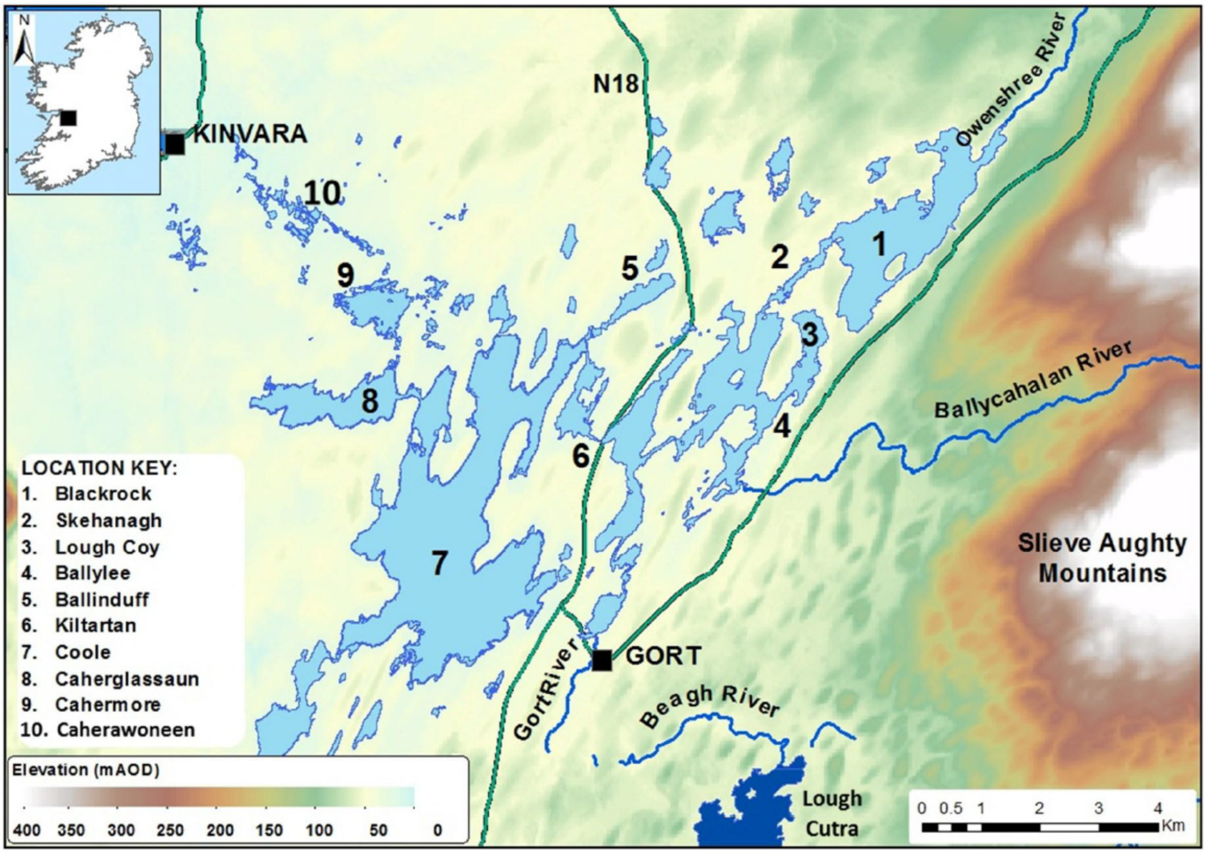
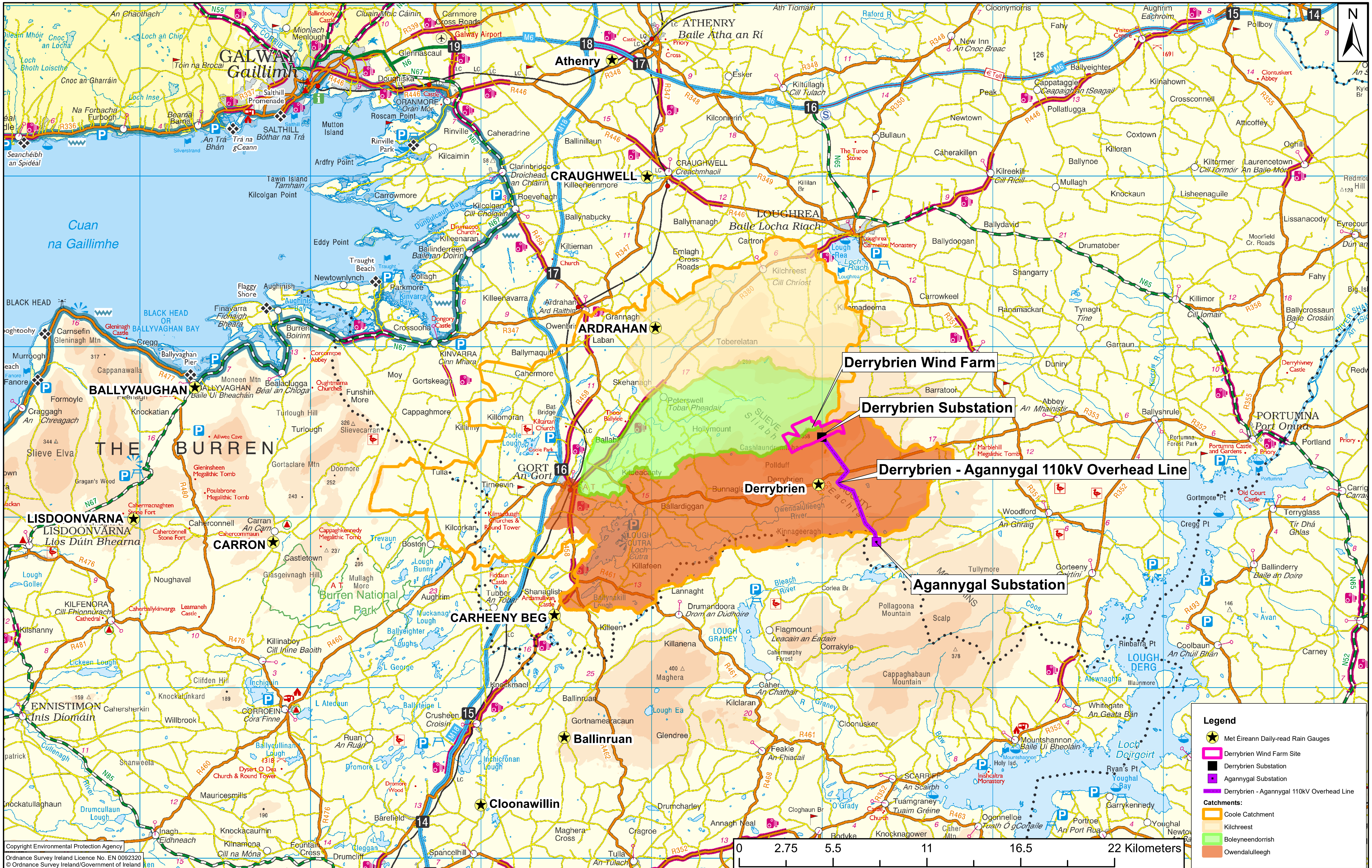



**Plate 2 – Groundwater Flood extent map for the Gort Lowland, winter 2015-2016 (copied from McCormack and Naughton, 2016)**

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DRAWING TITLE: Appendix 11B - Figure 5 Location of Daily-read rain Gauges in proximity to the Gort Lowlands



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## 4.2 Turlough Flooding

Turlough flooding occurs when for a sustained period the inflow exceeds the finite capacity of groundwater outflow from the turlough via its karst conduit flow system. During prolonged and intense rainfall, the subterranean flow paths are unable to drain its catchment and the limited subsurface storage is quickly exhausted resulting in surface flooding in the low-lying topographical depression. Under normal flood conditions this inundation is necessary for the flood-dependent turlough habitat. The excess floodwater builds up in the turlough basin which increases the heads available to drive increased groundwater outflow and / or continues to rise until it discharges as groundwater flow within the shallow epikarst and also overtops and spills overland. As water builds up in the turlough basin, this does not always necessarily increase the head available for the groundwater flow, as the water level in the downstream receiving turlough basins may also be rising due to their limited outflow capacity causing a backwatering effect. As the flood event proceeds and water levels continue to rise some of the turloughs become as one or become severely backwatered from the downstream turlough. Under normal flood conditions this inundation is necessary for the flood dependent turlough habitat. However, under extreme conditions extensive surface flooding and overland flow can develop, posing a flood risk to surrounding properties, roads and agricultural land.

A review of water level records in the various monitored turloughs of the Gort Lowlands clearly indicates a highly damped attenuated system where flood levels gradually rise, produce a prolonged peak and recede over many weeks. In these turloughs. The change can be dramatic between summer low levels and max winter flood levels, for example Coole Lough summer level is c. 5.5 mOD and the maximum winter flood level observed is 14.7 mOD (c. 9.2m depth difference).

The dye tracing carried out by David Drew (1994), GSI and the Gort Lowlands Flood Study (1997) shows multiple linkages to spring and turloughs from the various swallow-holes and turlough areas. These studies do not quantify the magnitude of these connections from these features only that there is a possible linkage. The main groundwater conduit flow linkages identified within the Gort Lowlands system are summarised as follows:

- Lough Bunny to Lough Skeardee and via Cloonteen River and swallow hole to Lough Mannagh and Hawkhill Turloughs
- Punch Bowl 2 km downstream of Lough Cutra, where the Beagh River from Lough Cutra sinks and rises at Pollduagh Cave at Cannahowna to the Cannahowna / Gort River.
- Blackrock Turlough to Lough Coy to Thor Ballylee Swallow-holes (Pollanoween and Pollaleen)
- Thoor-Ballylee Swallow-holes to Polldeelin Springs at Kiltartan and to the Lough Coole springs.
- The Gort River sinks at Pollatoophil swallow hole near Kiltartan castle and rises at Polldeelin Springs Kiltartan and to the Lough Coole Southern Springs

- Lough Coole-Garryland Turlough to Caherglassaun Turlough and also to the Kinvara springs
- Caherglassaun Turlough caves and swallow holes to Kinvara Springs (West, Central, and East)

## 4.3 Turlough overland spill pathways

As the inflow volume to the Gort Lowlands turlough basins exceeds the underground flow capacity of the karst conduit system the groundwater levels rise locally and the excess inflow volume is stored as standing water in the turlough basins. The turloughs continue to fill with the excess inflow until they spill overland or become joined with other nearby turloughs. The main overland flow spill pathways for the various Turloughs in the Gort Lowlands system are described as follows:

- Blackrock Turlough spills at Rahaly south in a southwest direction through Skehanagh to Carrowbaun East and onto the Ballylee floodplain at Newhall and Ballylee
- Overland flow from the Ballylee floodplain southwest via Rinrush and Deerpark to the Ballyloughaun Floodplain at the Athenry Rail line near the 44 mile post.
- The Castletown River at the Castletown Swallow-holes floods out and spills northwards to the Ballyloughaun floodplain crossing over the Castletown local road and the Galway-Ennis Railway line near the 44 milepost and joins with the Ballylee overflow in the Ballyloughlaun Floodplain.
- The Ballyloughaun floodplain spills westward across the R458 (formerly the N18) via the recently upgraded culvert crossing into the Kiltartan floodplain.
- The Kiltartan flood plain spills overland north to Corker turlough where it crosses west under the new M18 road to the Raheen turlough and south joining the Coole - Garryland Turlough
- To the south of Garryland-Coole Turlough the Cloonteen River drains Lough Mannagh to Hawkhill Turlough. Both Hawkhill and Newtown Turloughs all form part of the Garryland-Coole Turlough floodplain.
- The Garryland-Coole turlough spills northwards to Crannaghand then west into the Caherglassaun Turlough.
- Historically there is no overland spill from Caherblassaun Turlough to reach Cahermore Turlough located to the north.
- Cahermore Turlough spills northwards across the local Kinvara to Gort road c. 5km from Kinvara (southeast) and then spills overland northwest through Caherawoneen South and North to Shessaragh and eventually to Kinvara Bay to the northeast of Dungory Castle. This overland route was assisted by emergency flood relief works carried out by Galway Co. Co during the flood of 2015/2016.

## 4.4 Identified flood-prone areas requiring flood relief measures

A significant impact of flooding in the Gort Lowlands is the duration that areas are flooded or cut-off which extends to weeks and months during extreme events.

The main flood-prone areas identified by the OPW PFRA (Preliminary Flood Risk Assessment) Groundwater and GSI flood risk mapping, the previous flooding studies and by the current Gort Lowlands Flood Relief Scheme carried out by Ryan Hanley Consulting Engineers (Ryan Hanley, 2018b) are summarised as follows:

Cahermore Turlough Area

- Cahermore Turlough peak flood level is 13.6 mOD (Dec 15/Jan 16 event) (overland spill prevented this level rising further). There are at least 10 houses and up to 5 farm sheds/slatted sheds at risk including cut-off and flooding of local roads.

Caherglassaun Turlough Area

- Caherglassaun Turlough reported historical maximum flood level reached 14.48 mOD during 2015/2016 event. 1 house and slatted shed and large sections of local road flooded.

Garryland – Coole Turlough Area

- At Garryland – Coole Turlough System the reported maximum flood level from the 2015/2016 is 14.74 mOD. In this area three houses, a farm yard, warehouse and interpretative centre along with slatted sheds and numerous local roads and farm access roads and potentially the new M18 road at the Gort Interchange (based on evidence from 2015/16 flood).

Lough Mannagh area

- At Lough Mannagh south of the Coole-Garryland turlough system the historical maximum flood level was reported to be 15.15 mOD in the lough and 14.9 mOD in the floodplain on the north side of the Poulataggle Road during the 2015/16 event. Lough Coole and Garryland turlough back up in Lough Mannagh during extreme flooding. In this area there are up to 7 houses, Tirneevin Church and three slatted sheds at risk of flooding and a number of local roads and farm accesses.

Kiltartan floodplain area

- At Kiltartan floodplain the maximum historical flood level is c. 14.9 to 15.0 mOD for the 2015/16 event with Coole-Garryland Turlough reaching 14.7 mOD. There is significant flood risk at Kiltartan including the church (which has flooded on a number of occasions) and at least 5 houses classified and a number of farm sheds and a number of public local roads including private access roads.

Ballyloughaun and Castletown floodplains

- The Ballyloughaun and Castletown floodplains located to the east of the R458 (formerly the N18) at Kiltartan suffered its historical maximum flood level in the 2009 event when the R458 road flooded with a maximum flood level of 18 to 18.2 mOD. However during the 2015/16 flood event the maximum flood levels in the Ballyloughaun floodplain were between 16.2 and 16.5 mOD. This reduction in flood levels of 1.7 to

1.8 m was due substantially to the construction of a flood relief culvert under the R458 (former N18) road at Kiltartan (box culvert 2.9 m wide by 2.1 m in height) in the intervening years. Even at the much reduced flood levels in 2015/16 both the railway line and the Castletown road still flooded. No houses in the vicinity of this floodplain flooded or were at risk of flooding during either event. A number of local roads and the Limerick rail line (in excess of 400 m flooded) remain at significant flood risk.

Ballylee Floodplain Area

- At Thoor-Ballylee the peak flooding associated with the 2015/16 flood was of the order of 19.15 to 19.4 mOD. The main impact of flooding at Ballylee is flooding of the Thoor-Ballylee Yeats Centre, flooding of local roads leaving the Rinrush community cut-off and many houses stranded and access roads to farms and land cut-off.

Lough Coy

- The Ballylee floodplain backed up to Lough Coy in the 2015/16 flood event producing a maximum flood level of 19.5 mOD. At Lough Coy both 2009 and 2015/16 flood events produced similar maximum flood levels at Lough Coy. Such flood levels produce a flood risk to a number of slatted sheds and flood 350 m of the Dromorehill Road.

Blackrock Turlough

- The peak flood levels at Blackrock Turlough during the 2009 and the 2015/16 floods were surveyed at 29.45 and 29.15 mOD respectively. During the 2015/16 event at least 2 houses and 1 business flooded and almost 17 houses were cut-off. Flooding at Blackrock turlough produces a significant flood risk to 5 houses and 10 farm sheds in the vicinity of the turlough and many local roads and farm accesses may become submerged or cut-off.

# 5. Proposed Flood Relief Measures for Gort Lowlands

An extensive flood study of the Gort Lowlands catchment was carried out by Southern Global Water and Jennings’s O Donovan in 1996/1997 (SGW/JOD, 1997). This study outlined various potential flood mitigation options which involved –

- Improving the conveyance (overland channel flow) for water from the Coole area to get to the sea at Kinvara
- Impounding water upstream of the major flooded areas (4 large impoundment (i.e. dam) locations on the principal rivers including the damming of Lough Cutra, and the Ballycahalan River).
- Diverting flow to other catchments upstream of the major flooded areas.

None of these options were considered to be viable and therefore were not progressed any further. It was found given the duration and flood volumes involved that the damming was not viable economically nor very effective in reducing flooding downstream in the Coole Area (SGW/JOD, 1997).

As a consequence of more extreme flooding, particularly the 2009 and 2015/2016 events, a review of the flood relief options for the Gort Lowlands was implemented by the OPW/Galway County Council and this culminated in the appointment of engineering consultants Ryan Hanley to bring forward a viable flood relief scheme for the Gort Lowlands area. Ryan Hanley have through extensive surveys and assessments including the involvement of Trinity College, who are undertaking the groundwater modelling, identified a preferred flood relief solution that involves overland flood conveyance between turloughs and eventually to the sea at Kinvara Bay.

The preferred flood relief solution to the turlough flooding in the Gort Lowlands area is to lower the peak flood levels to prescribed target levels to protect, where feasible, properties that are at risk. These proposed reductions in flood level would typically be between 1 and 2 m at the 100 year design flood event. This solution would be in combination with raising local roads, the possible provision of alternative road access routes to cut-off communities, the possible relocation of some lower lying dwellings which cannot be feasibly protected and /or individual property defences (Ryan Hanley, 2019/2020).

The mechanism for lowering the peak turlough levels is through enhancing the existing overland spill pathways between turloughs allowing them to spill earlier and at a lower level so as to cascade from one turlough to the next in controlled overland channels with suitably sized culverts under local roads and accesses until reaching the sea at Kinvara (i.e. Blackrock to Ballylee to Ballyloughaun to Kiltartan to Corker to Coole-Garryland to Caherglassaun to Cahermore and to the sea at Dungory, Kinvara). The scheme requires a continuous overland pathway of spilling from one turlough to another to the sea and without such an integrated pathway to the sea, spilling from one turlough to another could potentially increase the flood risk in a given downstream turlough.

Other flood relief options such as upstream attenuation or land management on the inflowing tributaries of the Owenshree, Boleyneendorrish and Owendalulleegh Rivers as stand-alone measures or in combination with the above proposed overland conveyance measures are not very effective and in some cases not feasible given the sheer flood volume involved and the long duration (typically two months) required to protect these lowland areas. Such measures would have to involve damming of the river valleys for extended periods requiring the construction of major dams and the inundation of extensive area of upstream lands and only releasing a much smaller prescribed flow (i.e. 10 $m^3/s$ from Lough Cutra and 4 $m^3/s$ from Ballycahalan impoundments based on the Gort Lowlands Flood Study (Southern Global Water, 1997). It was also noted in this Study that the more serious turlough flooding of the lowlands areas occurred when prolonged winter rainfall over a 2-month period exceeded an average daily rainfall rate of 5 mm per day from the catchment. The total catchment area to Kiltartan is 301 $km^2$ and for the 2015/2016 flood event the average daily rainfall over a 66 day period was recorded at Derrybrien to be 10.8 mm/day. Restricting runoff from the catchment to 5 mm/day (17.4 $m^3/s$ ) would have required the storage of 5.8 mm/day which represents a storage volume of 115 million $m^3$ of runoff. This is equivalent to a lake 11.5 $km^2$ in surface area and 10 m average depth which could only be emptied over many months.

Large scale land management changes of the entire Slieve Aughty Mountains in terms of returning the hill slopes and plateau (watershed) areas, which are predominantly commercial forestry, to undrained peatlands will not produce the desired effect of achieving flood reduction in the downstream Gort Lowlands area. The blocking of drains and generation of more saturated conditions on the bog surface will only, at most, slow the rapid runoff of surface water but will have minimal effect on altering the flood volume generated, particularly for the prolonged winter flood events that cause the flooding in the downstream Gort Lowlands basin.

Attenuation and land management measures (i.e. restoring undrained peatlands and reducing drainage affects in forestry) can be effective in reducing the flood runoff rates for short duration flood events. Such measures are not very effective for prolonged winter rainfall events where the flood volume as opposed to the flood rate is critical, and this applies in particular to the case of the Gort Lowlands turlough flooding situation. These attenuation and land management measures do not provide a sink or longer-term store for rainfall with the volume of rainfall becoming the runoff volume particularly on these elevated winter-saturated catchments which have low permeability sub-soils overlying a low permeability agrillaceous limestone bedrock.

It is important to note that the Derrybrien wind farm site of 3.44 $km^2$ is a relatively small section of the overall Slieve Aughty Mountain catchment and therefore land use changes there have had no perceptible effect on flooding in the downstream Gort Lowlands catchment.

The proposed Gort Lowlands Flood Relief Scheme has serious challenges ahead to achieve a viable solution, both from cost-benefit and more critically from environmental impact perspectives. Environmentally there are likely to be very large challenges in respect to avoiding significant impact on European sites which include potentially the following Special Areas of Conservation (SAC) Natura Sites with the following turloughs classified as Annex I priority habitats:

- East Burren Complex SAC
- Coole-Garryland Complex SAC and SPA (Special Protection Area)
- Carrowbaun, Newhall and Ballylee Turloughs SAC
- Peterswell Turlough SAC
- Cahermore Turlough SAC
- Caherglassaun Turlough SAC
- Inner Galway Bay SPA
- Galway Bay Complex SAC

# 6. Derrybrien Wind Farm Project Potential Flood Impact

This section examines the potential downstream flood impacts from the Derrybrien Wind Farm Project on downstream flood receptors such as Lough Cutra and the turloughs within the Gort Lowlands area. The Derrybrien site measures 3.44 $km^2$ in area of which 66% drains to the Owendalulleegh River (i.e. 2.28 $km^2$) and 33% to the Boleyneendorrish River (i.e. 1.15 $km^2$) and 1% to the Duniry River (which is part of the Shannon System). The lands within the wind farm site represent disturbed peat bog with 263 ha formerly Coillte forestry plantation and 81 ha turbary bog lands. The peat slip area is 0.26 $km^2$ and the OHL corridor is 0.34 $km^2$, located in the Owendalulleegh Catchment and the southern end of the OHL in the neighbouring Bleach catchment draining to Lough Atorick which is almost entirely former Coillte Forestry. The total combined site area within the Owendalulleegh catchment is 2.86 $km^2$. The former turbary and forestry land uses introduced significant drainage of the mountain-side peatland giving rise to its disturbed and degraded peatland state. The wind farm project cleared Coillte forestry (felling approximately 28 ha of forestry between the wind farm site, landslide and OHL route), introduced additional floating roads and hardcored areas, increased the drainage network to protect the turbine bases, peat deposit sites, compound and substation sites and maintained and enhanced the existing drainage channels. The site was extensively drained prior to the wind farm project, with 27 km out of 39 km of drains on the site pre-existing the wind farm project. The remaining almost 12 km of drains on the site were constructed for the wind farm project.

The removal of trees from the site has enabled the peatland vegetation to re-establish in parts of the site and with some evidence of slow regeneration of blanket bog habitat on the site (see Chapter 7 – Biodiversity). Overall it is considered that the wind farm project through its drainage has increased the rate of runoff from the site. The natural runoff characteristics of this upland site prior to the project would be classified as a high flood runoff site. The effect of the wind farm project, as a worst-case assessment, is to increase the runoff class of the site from high runoff to very high runoff. This effect increases the peak flood rate as opposed to the total flood volume which will remain similar. The effect of this is more acute in the immediate locality of the site and rapidly diminishes downstream as the time to peak and the critical rain storm duration increase with the increasing catchment area of the receiving river. By the time it reaches the sensitive lower reaches of the Boleyneendorrish/Ballycahalan River upstream of the Thoor Ballylee turlough area (catchment 56 $km^2$) and the Owendalulleegh River upstream of Lough Cutra (catchment 90 $km^2$) the effect of increased runoff rates from the Derrybrien wind farm site will be very slight and imperceptible at the longer critical durations for flooding in these downstream receptors.

The estimated change using the FSU Equation for the inflow to Lough Cutra under an increase from high to very high runoff category lands achieved by reducing the BFI (baseflow index) in the FSU flood estimation equation is an increase of 0.58% in peak flood rate, increasing the annual maximum hydrograph peak (Qmed) from 31.07 m3/s to 31.25 m3/s. In the Boleyneendorrish catchment the impact of the wind farm Project on peak downstream fluvial flood rate at Cloonbeg will be an increase of 0.28% in peak flood rate, increasing the annual maximum hydrograph peak (Qmed) from 16.14 m3/s to 16.19 m3/s. The estimated potential increases in flood peak of 0.58% and 0.28% in the downstream reaches of these catchments is considered minor in the context of downstream flooding and will have no perceptible impact on flood levels and duration of flooding. The Derrybrien Wind Farm Project will not affect the overall flood volume discharging from the site which is the critical factor for flooding in the downstream Gort Lowlands area.

Attenuating and slowing the flow on the Derrybrien wind farm site to pre-existing Greenfield runoff rates is of little benefit with respect to reducing downstream flooding as this measure will potentially only delay the onset of flooding by a matter of hours whereas the downstream flooding occurs over weeks and months. Critical to the Gort Lowlands flooding is the total flood volume as opposed to the rate and as such the rainfall volume falling on the upland catchment will make its way to the Gort Lowlands area where it naturally stores until such time that it can empty to the sea via the groundwater system. The Gort Lowlands area acts as the natural floodplain and provides essential flood storage that protects surrounding and downstream lands from more serious flooding.

There is limited opportunity for flood risk management measures at the Derrybrien wind farm site. Such measures if applicable would involve slowing the flow through the provision of on-site flood storage attenuation through creating engineered attenuation reservoirs/dams and through damming drains. Such on-site attenuation measures would be ineffective given the nature of the flood risk in the downstream catchments which are caused by prolonged winter rainfall which is flood volume rather than flood rate sensitive. Attenuation is only effective for short duration events of hours as opposed to weeks. Over a prolonged flood period of weeks the same volume would be transmitted from the site with or without attenuation measures and therefore would have no effect on flooding in the critical Gort Lowlands area. Whether the site is a wind farm, forestry, cutaway bog or an upland blanket bog the same flood volume over a prolonged wet winter flood period would be generated and released downstream to Lough Cutra in the Owendalulleegh River and to Thoor Ballylee in the Ballycahalan. It also is important to note that construction of large reservoirs on the Derrybrien wind farm site or the blocking of the primary trunk drains could pose an unacceptable geotechnical stability risk with respect to any future peat slides.

The increased frequency of flooding in recent decades (i.e. commencing 1989/90 onwards) that has been witnessed in the downstream Gort Lowlands area is due to increased frequency and magnitude of prolonged winter rainfall events (critical duration four to eight weeks). Prior to the 1990s rainfall records show that the preceding decades of the 1960s, 1970s and 1980s were benign in comparison. There is no evidence to suggest that development of the wind farm in 2003 onwards is responsible for increased flooding in the downstream Gort Lowlands areas. The scale of the Gort Lowlands catchment relative to the Derrybrien wind farm site at less than 1% logically suggests minimal impact this is further reinforced given that the site prior to the wind farm Project was already a drained site for forestry and turbary extraction.

# 7. Conclusions

The flooding in the downstream Gort Lowlands is caused by extreme prolonged rainfall events and is a function of the flood volume generated from direct recharge to karst limestone basins and indirect fluvial flow from the upland impervious sandstone catchments of the Slieve Aughty Mountains. The flooding in the Gort Lowlands is not sensitive to the speed of the runoff from the mountains as the turloughs provide large natural storage basins that attenuate the runoff hydrograph over many weeks and only commence spilling overland when the storage capacity is exhausted which happens over weeks as opposed to hours.

It is clear from the flooding history that these lowland turlough areas have suffered the more extreme flooding from the 1990s onwards with no significant flooding identified in the previous 50 years (rainfall analysis by Southern Global Water, 1997). The cause of this is meteorological with the recent three decades producing a number of extreme and prolonged winter rainfall events in comparison to a relatively benign rainfall/flood period in the 1950s, 1960s, 1970s and 1980s. In other large winter-flood dominated catchments such as the River Shannon, in which records go back to the 1930s, the same flood pattern can be observed with more extreme flood events favouring the more recent three decades. For instance, the largest inflows from Lough Derg to the Lower Shannon since the Shannon Scheme commenced operation in 1929 have occurred during the 2009, 2015/16 and 2020 floods.

Flood relief solutions for the Gort Lowlands are being progressed by OPW/Galway Co. Co. through their consultants Ryan Hanley to protect vulnerable properties, farmyards, communities and roads in the Gort Lowlands area. The preferred flood relief options is to reduce turlough levels to specific target levels through engineering overland spill channels between turloughs until eventually reaching the sea at Dungory Kinvara. The proposed Gort Lowlands Flood Relief Scheme has serious challenges ahead to achieve a viable solution, both from a cost-benefit and possibly more challengingly from an environmental impact perspective.

In the case of Derrybrien, the former land use on the wind farm site was primarily commercial forestry and turbary which represents a drained bog situation and given it upland nature and gradients represents high flood runoff category land. The wind farm project introduced additional drainage and also maintained a number of the existing turbary drains. The drainage solution for the wind farm was not designed to extensively lower the water table level but focused on collecting and conveying surface water runoff away from the turbine bases and therefore for the scale of the 344 ha site the improved drainage does not represent a substantial network of drainage channels over its former forestry and turbary uses. The removal of trees from the site has enabled the peatland vegetation to re-establish throughout the site and with some evidence of slow regeneration of blanket bog habitat on the site, refer to ecology assessment. Overall it is considered that the wind farm Project through its drainage has increased the flood runoff rate over its former forestry and turbary uses from a high runoff category to a very high runoff category site. The effect of this on receiving surface water flood flows is assessed to be slight locally with the effect rapidly diminishing downgradient with increasing river catchment such that by the time it reaches Lough Cutra and the Thoor Ballylee floodplain areas from the respective Owendalulleegh and Boleyneendorrish Rivers the increased runoff rate is insignificant in respect to flooding and flood risk.

## References

Daly D (1985) “Groundwater in County Galway with particular reference to its protection from pollution.”, Geological Survey of Ireland report for Galway County Council.

Daly D (1992) “A report on the flooding in the Gort-Ardrahan area.” Geological Survey of Ireland, 209pp.

Drew D.P. and Daly D. (1993) “Groundwater and karstification in mid-Galway, South Mayo and North Clare”, Dept of Transport Energy and communications, ISBN 0790-0279.

EPA Hydronet Resource – www.epa.ie/hydronet/#29071

GSI (2020) https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx#KarstFeaturesGSI (2019) “Maximum Historical Groundwater Flooding Extents” Shape files for the Gort Lowlands Catchment.

Jennings O’Donovan (2011) “Review of the South Galway Flood Study Report- Engineering proposals for the reinstatement of culverts on the N18 and the Provision of New culverts on Minor Roads at Kiltartan, - Feasibility of an overland Channel from Coole to Kinvara”, report to OPW Jan 2011.

McCormack T. and Naughton O. (2016) “Groundwater Flooding in the Gort Lowlands”, GSI Newsletter, 2016.

Met Eireann (2020) https://www.met.ie/cms/assets/uploads/2018/07/IE_AAR_8110_V1.txt

Morrissey P, Gill L, Naughton O., McCormack T. and Johnston P. (2018) “Groundwater flood modelling in the karst lowlands of South Galway.”

NERC 1975 “Flood Studies Report” Vol 1 to 5, Natural Environmental Research Council, London.

OPW (1994) “Report on Flooding in South Galway in 1994” OPW Engineering Services, May 1994.

Southern Water Global / Jennings & O’Donovan (1997) “An Investigation of the Flooding Problems in the Gort-Ardrahan area of South Galway – Final Report. Vol 1 to 3.”, OPW?, April 1997.

Walsh S. (2010). “Report on Rainfall of November 2009”, Met Eireann, Dublin Ireland.